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Department of Agriculture
Government of Western Australia



**Soils of the Ivanhoe West Bank
East Kimberley
Western Australia**

*by Noel Schoknecht and
Chris Grose*

March 1996



**RESOURCE MANAGEMENT
TECHNICAL REPORT 155**

Summary

A brief assessment of the soils, and their suitability for irrigated agriculture, of 2,064 ha on the Ivanhoe West Bank was conducted in May-June 1994.

Sandy or loamy soils occur on broad levees adjacent to the Ord River, and areas of 'black soil' and 'red soil' plains occur behind the levees. Some areas of the red soil plain and levees are deeply dissected, and occasional active erosion is evident.

A preliminary assessment of the suitability of the map units for flood and spray or trickle irrigation has been made:

For **flood irrigation** 446 ha (22%) are considered suitable, 955 ha (46%) marginally suitable, and 663 ha (32%) unsuitable or not assessed.

For **spray or trickle irrigation** 1,336 ha (65%) are considered suitable, 65 ha (3%) marginally suitable, and 663 ha (32%) unsuitable or not assessed.

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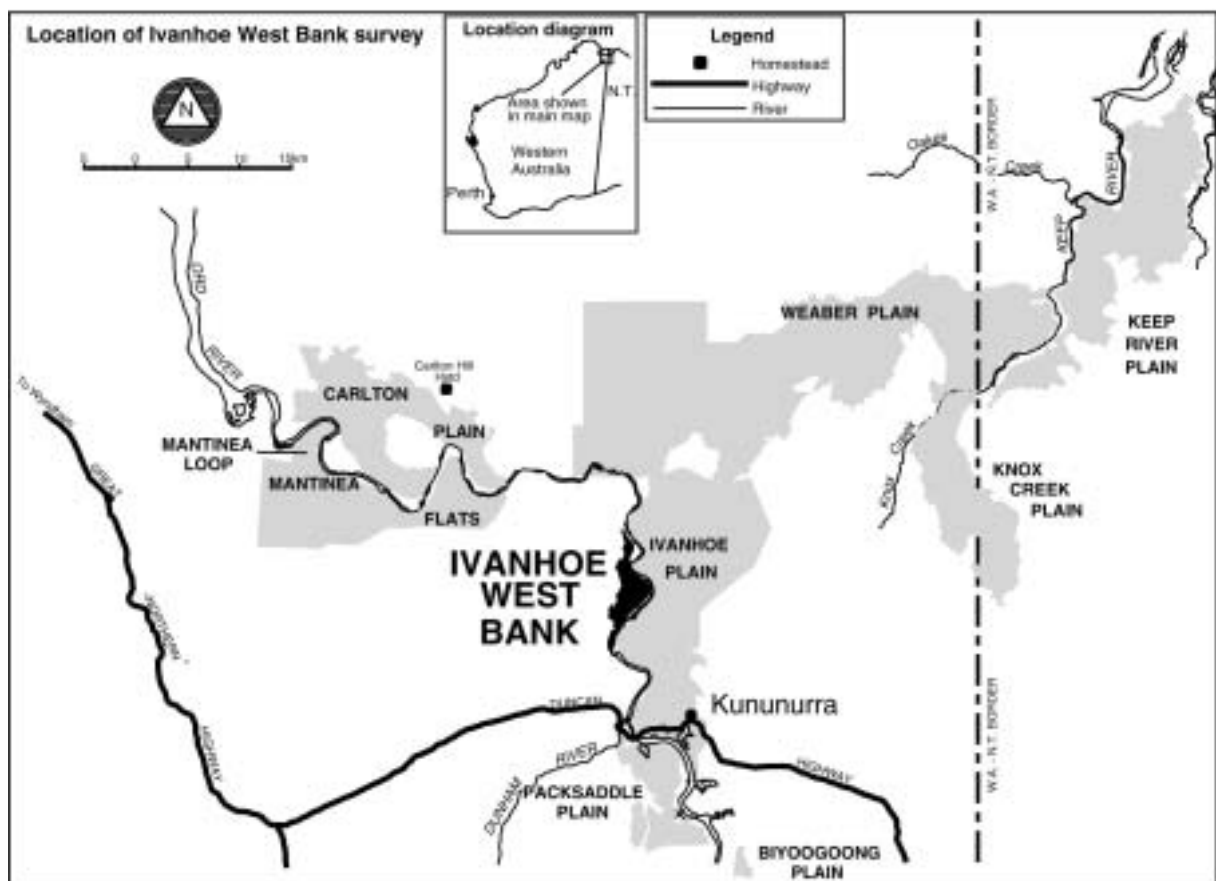
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1. Introduction

This study was requested by the Ord Stage 2 Steering Committee to provide basic soil and landscape information for an area of land known as the Ivanhoe West Bank. This information has been used to enable an assessment of the suitability of the study area for irrigated agriculture and to assist planning for possible expansion of the Ord River Irrigation Area (ORIA).

The Ivanhoe West Bank covers 2,064 ha situated on the western side of the Ord River, opposite the Frank Wise Research Institute, about 15 kilometres NNW of Kununurra.



Location of the Ivanhoe West Bank and relation to other potential irrigation areas.

2. History of land use

The area was first settled in the 1880s and has been used for cattle grazing since then. The survey area is presently within Ivanhoe Station and is used for grazing of Brahman, Shorthorn and Brahman-Shorthorn cross cattle on native grasslands and woodlands.



The survey area was accessed from Kununurra by crossing the Ord River at Ivanhoe Crossing.

3. Climate

The area is semi-arid with summer monsoonal rains. Average rainfall for Kununurra is 778 mm, most of which falls in the four months December to March, with the rest of the year a virtual drought. The mean maximum temperatures range from 30.5⁰C in July to 38.8⁰C in November and mean minima range from 14.2⁰C in July to 24.8⁰C in December. The area is virtually frost-free (Delane 1987).

4. Geology and physiography

The Ivanhoe West Bank comprises Quaternary alluvium (primarily Qa, and minor Czs - Cambridge Gulf 1:250,000 Geology map) derived from regular flooding and alluvial deposition from the Ord River. Fine to coarse-grained sands have been deposited adjacent to the river to form levee banks. Behind the levee banks are finer grained deposits, including significant areas of clayey black soil alluvium. Coarse sands, gravels and stones are deposited on the inside of meander loops beside the Ord River.

Minor rock outcrops adjacent to the Ord River are composed of Devonian quartz sandstone (south of Button's Crossing) and Lower Cambrian basalt (Ivanhoe Crossing).



The Ord River cutting into levee soils adjacent to the survey area near Button's Crossing.

5. Native vegetation

The native vegetation is predominantly savanna comprising a tussock grassland understorey and scattered shrub or tree overstorey (Beard 1990), or open woodlands. Plant names are from Wheeler *et al.* (1992).

The main tree on the cracking clay plains is *Lysiphyllum cunninghamii* (bauhinia). Trees and shrubs on the red soil plains, levees and sandy colluvial slopes include *Eucalyptus tectifica* (grey box), *E. microtheca* (flooded box), *Adansonia gregorii* (boab), *Lysiphyllum cunninghamii* (bauhinia), *E. curtipes*, *E. pruniosa* (silverleaf box), *E. confertiflora* (roughleaf cabbage gum) and *Hakea arborescens* (common hakea).

Common grasses of the cracking clay plains include *Iseilema vaginiflorum* (red Flinders grass), *Aristida latifolia* (feathertop wiregrass) and *Astrebla squarrosa* (bull Mitchell grass). *Themeda triandra* (kangaroo grass), *Heteropogon contortus* (bunch or black speargrass) and *Panicum airoides* (creeping panic) occur on the levees. A range of grasses including *Sporobolus australasicus* (Australian dropseed), *Brachyachne convergens* (common native couch), *Themeda triandra* (kangaroo grass) and less commonly *Aristida hygrometrica* (northern kerosene grass) and *Enneapogon purpurascens* (purple nineawn) grows on the red soil plains.

6. Survey methods

Previous surveys

The first survey of the area was a reconnaissance of about 300,000 ha between Wyndham and the Western Australian-Northern Territory border in 1944 by a team from the Lands and Surveys Department. The soils were described by Burvill (1991). This survey was conducted to identify areas with potential for irrigated agriculture. The Ivanhoe West Bank (called Ivanhoe homestead in Burvill's report) was identified as an area of potential, but no detailed soils information was gathered.

A land system survey of the Ord-Victoria area was conducted in 1949 and 1952 and published by Stewart *et al.* (1970). Within this survey, the alluvial Knox Creek Plain was described as the Ivanhoe Land System.

The soils of the Ivanhoe Plain on the east of the Ord River were described by Aldrick *et al.* in 1990.

Ivanhoe West Bank survey

Preliminary map units were marked on 1:20,000 colour photographs (taken July 1993), and examined in the field considering features such as soil, landform, microrelief and vegetation.

Fieldwork was conducted by Noel Schoknecht and Chris Grose over six days during May and June 1994.

Fifty sites were examined. Soil profiles were obtained by pushing a 50 mm steel tube down to about 100 to 120 cm with a Gemco drill rig. Each profile was examined for a minimum of texture, colour, structure, depth of horizons, pH and electrical conductivity (EC). Soils were described according to the *Australian Soil and Land Survey Field Handbook* (McDonald *et al.* 1990) and the accompanying WA Technical Report (Purdie 1993).

On the basis of the profile descriptions, general observations, information from previous surveys and discussions with Kununurra staff, soils were described, map units delineated and assessments made.

7. Map units

A common map key to link the map units throughout all the surveys of the Ord River Irrigation Area has been created based primarily on the map units identified by Aldrick and Moody (1977) on the Lower Weaber and Keep River Plains (1977) and Aldrick *et al.* (1990) in the study of the Ivanhoe Plain. This common key has been expanded to incorporate surveys of the Weaber Plain, Ivanhoe West Bank and the Knox Creek Plain. Not all of the units of the common map key occur within this survey area and thus map unit designations are not necessarily consecutive. The common map key is presented in Appendix 1.

The distinction between a soil unit and a mapping unit must be understood. Map units, which can also be termed 'land units', include a combination of land features in their identification. These include landform, vegetation, flooding, drainage and stoniness in addition to soil type. A soil unit describes only the soil features.

Map units identified on the Ivanhoe West Bank were:

1 **Flat to very gently undulating cracking clay plain**

This comprises areas of brown or grey cracking clay soils, mainly **Cununurra leached grey** or **brown phase**, and occasionally **Cununurra eroded phase**. These soils are locally known as 'black' or 'Cununurra clays'. Slopes of less than 1% are common. This unit often occurs as small apparently remnant areas which have yet to be removed by erosion. The soils frequently intergrade with the red or brown soils of the adjacent red soil plain.

A tall tussock grass savanna is the main vegetation community. The most common tree is *Lysiphyllum cunninghamii* (bauhinia), and grasses include *Iseilema vaginiflorum* (red Flinders grass), *Aristida latifolia* (feathertop wiregrass) and *Astrebla squarrosa* (bull Mitchell grass).

2f **Almost flat red soil plain**

This flat to gently undulating unit with slopes to 2% comprises areas of variable red or brown soils ('**red plain**' soils). Similar soils were described by Stoneman (1988) as Packsaddle sandy loam, and by Aldrick (1990) as Weaber family. The soils were not studied in sufficient detail to determine the full range of characteristics, however common properties include a red or less commonly brown colour, and a hard apedal loamy or clay loamy surface, grading or changing abruptly into a structured heavier clayey subsoil. The surface is often hard and dense. In many areas variable sheet erosion has occurred, and some sections are bare of grass.

A tall tussock grass savanna is the dominant vegetation community. The main trees are *Eucalyptus tectifica* (grey box), *E. microtheca* (flooded box), *Adansonia gregorii* (boab) and *Lysiphyllum cunninghamii* (bauhinia). Scattered trees include *E. curtipes*, *E. pruniosa* (silverleaf box), *E. confertiflora* (roughleaf cabbage gum) and *Hakea arborescens* (common hakea). Common grasses include *Sporobolus australasicus* (Australian dropseed), *Themeda triandra* (kangaroo grass) and *Brachyachne convergens* (common native couch), and less

commonly *Aristida hygrometrica* (northern kerosene grass), *Heteropogon contortus* (bunch or black speargrass) and *Enneapogon purpurascens* (purple nineawn).

2g Dissected red soil plain

Drainage from within the study area and the surrounding hills has dissected areas of the red soil plain and the levees. These dissected areas are generally vegetated, with active erosion large enough to be included in map unit 2h. The soils and vegetation are variable and were not studied in detail.

2h Active erosion

A few areas of the red soil plain are actively eroding. In many cases the underlying carbonate-rich subsoils are exposed. These subsoils have a high pH and may also be saline. The areas are usually devoid of vegetation, except perhaps for a few early coloniser species.

5b Flat plain of clay soils with hydromorphic attributes, seasonally inundated to shallow depths for short periods

This occurs in depressed bands that are seasonally inundated. These bands are often swales between rises in the levee or red soil map units. Grey cracking clay soils predominate - typically **Aquitaine greyish phase** or occasionally **Cununurra clay leached grey phase**.

The native vegetation consists of a tall tussock grassland with a few very scattered trees or shrubs. Dominant grasses include *Iseilema vaginiflorum* and *Aristida latifolia* (feathertop wiregrass). Occasional trees and shrubs include *Lysiphyllum cunninghamii* (bauhinia) and *Acacia farnesiana* (mimosa bush).

6c Rock outcrop

These are moderate to steep slopes with very shallow rocky soils. Native vegetation is a spinifex hummock grassland with scattered shrubs.

7c Flat to gently undulating levee plain

These levee plains comprise the major survey unit. The slopes generally range from 0 to 3%, although steeper slopes occur beside the Ord River. On the outside of meander bends in the river, floods have sometimes eroded vertical faces. The pattern of numerous rises within the levee plain relates to previous alignment of the Ord River. Sandy or loamy levee soils predominate (**Ord sandy loam**).

A tall tussock grass tree savanna is the predominant vegetation community. Common grasses, include *Heteropogon contortus* (bunch or black speargrass), *Themeda triandra* (kangaroo grass) and *Panicum airoides* (creeping panic). Common, but scattered trees include *Eucalyptus microtheca* (flooded box), *E. confertiflora* (roughleaf cabbage gum or similar), *Lysiphyllum cunninghamii* (bauhinia) and *Adansonia gregorii* (boab). Various shrubs, herbs and creepers are also common.

7d Recent sand and gravel/stone river deposits

These are sandy to stony point-bar deposits (sediment deposited on the inside of a meander loop) adjacent to the Ord River. These areas are generally bare of vegetation, and have little or no soil development.

7e Slopes of eroded levee, lower terraces, rare rock outcrop near river, seasonally inundated

This includes the steeper and sometimes eroded parts of the levee unit 7c next to the Ord River. It also includes lower river terraces and occasional rock outcrops. The soils are variable sands to loams.

The vegetation is similar to unit 7c, with *Ficus coronulata* (peach-leaf fig) growing on the river banks.

11 Colluvial outwash slopes below sandstone hills

This unit covers the sandy colluvial slopes below the rocky hills. The soils are invariably sandy, and a mottled clay subsoil is common. The vegetation is a savanna or open woodland. Detailed site information on the soils and vegetation was not recorded.

L Lagoons - permanent water

These are lagoons and depressions which contain permanent water.

Sw Swamps/depressions

This unit covers swamps and depressions which are seasonally inundated. Soils are typically heavy grey cracking clays.

Table 1. Areas of map units.

Map unit	Area (ha)
1	381
2f	369
2g	309
2h	14
5b	65
6e	46
7c	586
7d	120
7e	165
L	3
Sw	6
TOTAL	2,064

Note: The area of map unit 11 was not determined.

8. Soils

Where possible the soil names used by Aldrick *et al.* (1990) have been retained, with modifications or additions to suit the local soils. The main soils of the study area are described:

Cununurra family (Cununurra cracking clays)

The Cununurra family of soils includes most of the soils in the ORIA. Previous surveys identified several phases based on pH, colour, drainage and degree of erosion (Aldrick *et al.* 1990, Burvill 1991, Dixon 1996, Schoknecht and Grose 1996). The Cununurra clays identified within the ORIA by these authors are identified and compared in Table 2.

The Cununurra clays of the Ivanhoe West Bank generally fit within the leached (grey and brown phases) and eroded phases identified in these surveys. Their occurrence is very limited. They often intergrade with soils of the adjacent red soil plain and are therefore very variable.

Leached phase

Grey cracking clays with a neutral to slightly acidic surface are the predominant Cununurra clays in the study area. Brown variants occasionally occur also.

Typical profile Cununurra clay leached grey phase (site 29)

Horizon	Depth (cm)	Description
A1	0-10	Dark greyish brown (2.5Y 4/2) medium clay; strong subangular blocky structure 5-10 mm; pH 7.3; very few fine manganiferous concretions; clear boundary.
B2	10-80	Dark greyish brown (2.5Y 4/2) medium heavy clay; moderate angular blocky structure 5-10 mm; pH 9.0; very few fine manganiferous concretions; gradual boundary.
B3	80-120+	Dark greyish brown (2.5Y 4/2) medium heavy clay; structure not determined; slickensides; pH 9.5; very few fine calcareous and manganiferous concretions.

Australian Soil Classification: Epipedal Grey Vertisol
(Isbell 1995)

Eroded phase

These soils sometimes occur on the edge of the black soil remnants, but are not common in the survey area. They are grey or brown phases which have been eroded to varying degrees.

Table 2. Forms of Cununurra clays found in different surveys.

Phase	Survey	Key features
Normal	<ul style="list-style-type: none"> • Burvill • Ivanhoe Plain • Lower Weaber and Keep Plains • Weaber Plain 	<ul style="list-style-type: none"> ◆ Main colour dark (V/C=1) ◆ Topsoil tilth medium ◆ Virgin topsoil pH 7.5 to 8.0 ◆ Some carbonates in upper profile, increasing with depth ◆ Drainage poor
Alkaline	<ul style="list-style-type: none"> • Ivanhoe Plain • Weaber Plain 	<ul style="list-style-type: none"> ◆ Main colour brown (V/C=5) ◆ Topsoil tilth fine ◆ Virgin topsoil pH 7.8 to 8.5 ◆ Carbonates present throughout, including surface ◆ Drainage imperfect to poor
Leached	<ul style="list-style-type: none"> • Ivanhoe Plain • Weaber Plain 	<ul style="list-style-type: none"> ◆ Main colour grey (V/C=2) ◆ Topsoil tilth cloddy ◆ Virgin topsoil pH 6.8 to 7.8 ◆ No carbonates except few low in profile ◆ Drainage poor to very poor
Subgroups		
Leached grey	<ul style="list-style-type: none"> • Knox Creek Plain 	<ul style="list-style-type: none"> ◆ Grey
Leached grey-gypsic	<ul style="list-style-type: none"> • Knox Creek Plain 	<ul style="list-style-type: none"> ◆ Grey, free gypsum crystals in lower B horizon
Leached brown	<ul style="list-style-type: none"> • Knox Creek Plain 	<ul style="list-style-type: none"> ◆ Brown
Leached brown gypsic	<ul style="list-style-type: none"> • Knox Creek Plain 	<ul style="list-style-type: none"> ◆ Brown, free gypsum crystals in lower B horizon
Eroded	<ul style="list-style-type: none"> • Burvill • Weaber Plain 	<ul style="list-style-type: none"> ◆ Similar to normal but severe gully-erosion ◆ Slight to almost total truncation
Browner	<ul style="list-style-type: none"> • Lower Weaber and Keep Plains 	<ul style="list-style-type: none"> ◆ Browner than normal ◆ Supports dense stands of <i>Lysiphyllum cunninghamii</i> ◆ Possibly shallower and drier
Darker	<ul style="list-style-type: none"> • Lower Weaber and Keep Plains • Weaber 	<ul style="list-style-type: none"> ◆ Similar to normal but darker in colour
Flooded/Wetter	<ul style="list-style-type: none"> • Burvill • Ivanhoe • Weaber • Lower Weaber and Keep Plains 	<ul style="list-style-type: none"> ◆ Similar to leached ◆ Upper soil colour grey, subsoil often pale grey ◆ Seasonally inundated ◆ Very poorly drained ◆ Intergrades with Aquitaine soils

Aquitaine family

Aquitaine greyish phase (Aldrick 1990)

These soils occur where annual inundation is significant. The soils are usually distinctly gilgaied, and in some areas a ‘debil-debil’ type microrelief (distinct hummocks and hollows up to 30 cm high and 0.5 to 1 m spacing) has developed.

Typical profile (site 33)

Horizon	Depth (cm)	Description
A11	0-5	Dark grey (2.5Y 4/1) medium clay; strong subangular blocky structure 5-10 mm; pH 7.6; clear boundary.
A12	6-40	Dark grey (2.5Y 3.5/1) medium heavy clay; moderate subangular blocky structure 20-50 mm; pH 8.6; very few fine calcareous and manganiferous nodules; gradual boundary.
B2	40-60	Dark grey (2.5Y 3.5/1) heavy clay; moderate prismatic structure 50-100 mm; slickensides; very few fine calcareous and manganiferous nodules.

Australian Soil Classification: Epipedal Grey Vertosol
(Isbell 1995)

Levee soils

The main levee near the Ord River is Ord sandy loam. It was first described by Burvill (1990) in the Carlton Reach survey undertaken in 1944. The soil is typically a red or brown, fine loamy sand or sandy loam grading to a fine sandy clay loam at depth. Fine sandy alluvium often underlies the soil at greater than 1 m. Variants of this soil include uniform fine sandy loams throughout, or heavier fine sandy clay loam subsoils. The lighter textured variants are also called **Ord loamy sand** (Riley *et al.* 1993). The levee soils are well suited to horticulture because of their fine sandy to loamy textures, neutral pH and good drainage.

Typical profile (site 9)

Horizon	Depth (cm)	Description
A1	0-20	Dark reddish brown (5YR 3/2) loamy fine sand; weak subangular blocky structure 5-10 mm; pH 7.3; diffuse boundary.
AC	20-120+	Brown (7.5YR 4/4) light fine sandy loam; apedal; pH 7.4.

Australian Soil Classification: Basic Orthic Tenosol
(Isbell 1995)

'Red plain' soils

A group of red soils occurs on the plain behind the river-fringing levee soils. These are very variable and often eroded. The topsoils, especially in eroded areas, are hard and compact, and may be devoid of vegetation. The soils are usually red or less commonly brown and often grade into the levee soils. Surface textures vary from sandy loams to sandy clay loams, although in eroded areas a clayey subsoil may be exposed. The lighter textured topsoil may grade, or change abruptly, into the heavier textured subsoil.

The red plain soils include the Packsaddle sandy loam (Stoneman 1988, Riley 1993) and the Weaber family soils described by Aldrick *et al* (1990).

Further investigation is required to determine the full range of soils present.

9. Land use interpretation

Suitability for irrigated agriculture

A preliminary assessment of the suitability of the map units for flood and spray or trickle irrigation is provided below. Further more detailed soil survey and chemical and physical analysis is required to indicate precise areas of suitable land within the survey area.

Map unit 1

The black soil plains are well suited to irrigated agriculture, and widely used for flood irrigation on the Ivanhoe Plain. The main limitation for irrigation would be the small areas and often isolated occurrences.

Map unit 2f

The uneroded red soil plain areas are suitable for irrigated agriculture, especially spray and trickle irrigation. Similar areas on the Packsaddle Plain have been used for a variety of horticultural crops including bananas, mangoes and vegetables.

Map unit 2g

The dissected red soil plain is generally too steep for irrigated agriculture.

Map unit 2h

The areas of active erosion are not suitable for irrigated agriculture.

Map unit 5b

Surface drainage of this unit would be necessary before irrigation could proceed. These soils are poorly drained internally, and waterlogging could limit irrigation, although they have been successfully irrigated on the Ivanhoe Plain. Problems may also occur with topsoil tilth. In the study area this unit is limited and often occurs in narrow bands. It is considered marginally suitable for irrigated agriculture.

Map unit 6c

Rock outcrops, not suitable for irrigated agriculture.

Map unit 7c

The levee soil plains are highly suited to spray or trickle irrigation. They are only marginally suitable for flood irrigation because of slope and the high infiltration rates.

Map unit 7d

The coarse sandy and stony deposits beside the Ord River which are seasonally inundated are not suitable for irrigated agriculture.

Map unit 7e

This is not suitable for irrigated agriculture because of steep slopes, seasonal inundation, rock outcrop and proximity to the Ord River.

Map unit 11

The colluvial outwash slopes below the rocky hills were outside the designated study area and only examined briefly. These soils are predominantly sandy surfaced, and may have scope for trickle or spray irrigation. Further investigation would be required to map suitable areas.

Map unit L

The lagoons with permanent water are not suitable for irrigated agriculture.

Map unit Sw

The swamps which are seasonally inundated and have very variable, often clayey soils are not suitable for irrigated agriculture. The areas were not examined to determine suitability if drained.

Table 3. Summary of suitability for flood irrigation.

Map unit	Suitability	Limitations
1	Suitable	Some areas are small and isolated
2f	Marginally suitable	Some areas are eroded; areas often small or isolated
2g	Unsuitable	Dissected slopes, risk of erosion
2h	Unsuitable	Actively eroded soils, exposed inhospitable subsoils
5b	Suitable	Surface drainage may be required; some areas may be too small or isolated
6c	Unsuitable	Rock outcrop
7c	Marginally suitable	High infiltration soils on gentle slopes
7d	Unsuitable	Sand/gravel deposits near the Ord River; seasonal inundation.
7e	Unsuitable	Steep slopes, variable soils; seasonal inundation
11	Unsuitable	Slopes with high infiltration and sandy soils
L	Unsuitable	Permanent water
Sw	Probably unsuitable - not assessed	Would require drainage

Table 4. Summary of suitability for spray or trickle irrigation.

Map unit	Suitability	Limitations
1	Suitable	Some areas are small and isolated
2f	Suitable	Some areas are eroded; areas often small or isolated
2g	Unsuitable	Dissected slopes, risk of erosion
2h	Unsuitable	Actively eroding soils; exposed inhospitable subsoils
5b	Marginally suitable	Surface drainage may be required Some areas may be too small or isolated
6c	Unsuitable	Rock outcrop
7c	Suitable	Extensive areas of levee soils
7d	Unsuitable	Sand/gravel deposits near the Ord River; seasonal inundation
7e	Unsuitable	Steep slopes, variable soils, seasonal inundation
11	Possibly suitable - not fully assessed	Slopes with high infiltration sandy soils
L	Unsuitable	Permanent water
Sw	Probably unsuitable - not assessed	Would require drainage

Salinity and drainage

One of the major concerns for the long-term viability of irrigation in the ORIA is the risk of salinity caused by rising saline groundwater. Investigation of the electrical conductivity (EC 1:5 mS/m) of the soils in the Ivanhoe West Bank did not show any marked accumulation of salts throughout the soil profiles. Deep subsoil investigations (below 1.5 m) however were not conducted.

The proximity of the Ivanhoe West Bank study area to the Ord River, the plain's significant elevation above the river, the absence of high watertables after preliminary hydrogeological drilling (Nixon pers. comm.), and the observed presence of gravel beds below some levee soils would indicate that subsoil drainage should be adequate and high watertables unlikely to develop following irrigation. Salinity, especially of the levee soil areas, is therefore considered to be a low hazard under well designed and managed irrigation.

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Appendix 1. Common map key of Ord River Irrigation Area

Unit	Description	Survey
1	Cracking clays (Cununurra normal phase); relatively uniform over large areas of broad plains, minor inclusions of Cununurra wetter, darker and browner phases and some variation in topsoil pH. Vegetation variable, but mostly treeless.	<ul style="list-style-type: none"> • Ivanhoe West Bank • Weaber Plain • Lower Weaber - Keep Plains
1a	Brownish cracking clays with finely structured high pH topsoils (Cununurra alkaline phase); relatively uniform over large areas of broad plains; minor inclusions of calcareous soils with finely divided carbonates. <i>Lysiphyllum cunninghamii</i> woodland.	<ul style="list-style-type: none"> • Ivanhoe Plain
1b	Greyish cracking clays with relatively coarsely structured almost neutral pH topsoils (Cununurra leached phase); relatively uniform over large areas of broad plains; minor inclusions of Cununurra wetter phase. Mostly treeless.	<ul style="list-style-type: none"> • Ivanhoe Plain
1c	Brownish cracking clays (Cununurra leached and brown phases); northern parts of the Knox Creek Plain.	<ul style="list-style-type: none"> • Knox Creek Plain
1d	Greyish cracking clays with relatively coarsely structured almost neutral pH topsoils (Cununurra leached phase).	<ul style="list-style-type: none"> • Knox Creek Plain
1ds	As for 1d, but with a stony surface.	<ul style="list-style-type: none"> • Knox Creek Plain
1e	Channels/depressions in cracking clay plain; grey and brown cracking clays.	<ul style="list-style-type: none"> • Knox Creek Plain
1f	Cracking clay plain with complex pattern of minor remnant levees.	<ul style="list-style-type: none"> • Knox Creek Plain
1g	Grey cracking clays with self-mulching surface, carbonate and manganese nodules and gypsum crystals at depth.	<ul style="list-style-type: none"> • Knox Creek Plain
2a	Red-brown Earths* (Bonaparte normal phase); occurs as 'islands' in broad cracking clay plains. Low eucalypt woodlands.	<ul style="list-style-type: none"> • Lower Weaber - Keep Plains
2b	Red-brown Earths* with sandy topsoils (Bonaparte sandy-surfaced phase); occurs in association with unit 2a as 'islands' in broad cracking clay plains. Variable tall woodland or open forest.	<ul style="list-style-type: none"> • Weaber Plain • Lower Weaber - Keep Plains

Unit	Description	Survey
2c	Red earths with sandy topsoils (Weaber normal phase); occurs as 'islands' in broad cracking clay plains. Eucalypt woodland.	<ul style="list-style-type: none"> •Ivanhoe Plain •Weaber Plain •Lower Weaber - Keep Plains
2d	Red earths with abundant gravel throughout (Weaber gravelly phase); occurs on raised, linear, old steam bed areas; non-arable; sources of gravel. Eucalypt woodland.	<ul style="list-style-type: none"> •Weaber Plain •Lower Weaber - Keep Plains
2e	Red earths with heavy textured topsoils (Weaber heavier phase); occur as 'islands' in broad cracking clay plains. Eucalypt woodland.	<ul style="list-style-type: none"> •Ivanhoe Plain
2f	Almost flat red soil plain; red soils, usually loams or clay loams over clay (duplex); hardsetting surface.	<ul style="list-style-type: none"> •Ivanhoe West Bank
2g	Dissected red soil and levee plain; some areas of active erosion; variable soils, often with red clayey subsoil, exposed.	<ul style="list-style-type: none"> •Ivanhoe West Bank
2h	Active erosion, inhospitable subsoils high in carbonates, exposed.	<ul style="list-style-type: none"> •Ivanhoe West Bank
3a	Red-brown Earth*/Solodic Soil intergrades (Benton); occurs in association with other 2, 3 and 4 land units within broad clay plains; contains seasonally inundated depressions. Thick <i>Melaleuca minutifolia</i> woodland.	<ul style="list-style-type: none"> •Lower Weaber - Keep Plains
3a1	Red-brown Earth*/Solodic Soil intergrades (Benton); occurs in association with other 2, 3 and 4 land units within broad clay plains; contains seasonally inundated depressions. Treeless.	<ul style="list-style-type: none"> •Lower Weaber - Keep Plains
3b	Red-brown Earth*/Solodic Soil intergrades (Benton); occurs in association with other 2, 3 and 4 land units within broad clay plains; contains seasonally inundated depressions. <i>Grevillea striata</i> open woodland.	<ul style="list-style-type: none"> •Lower Weaber - Keep Plains
3c	Red-brown Earth*/Solodic Soil intergrades (Benton); on narrow areas and cracking clay intergrades (Milligan) on broad areas; occurs in association with other 2, 3 and 4 land units within broad clay plains; contains seasonally inundated depressions. <i>Eucalyptus microtheca</i> open woodland.	<ul style="list-style-type: none"> •Lower Weaber - Keep Plains

Unit	Description	Survey
3d	Cracking clay intergrades (Milligan) and Red-brown Earth/Solodic Soil intergrades (Benton); occurs in association with other 2, 3 and 4 land units within broad clay plains; contains seasonally inundated depressions. <i>Eucalyptus papuana</i> open woodland.	<ul style="list-style-type: none"> • Lower Weaber - Keep Plains
4a	Cracking clays (Cununurra) in large depressions, various non-cracking soils (Bonaparte, Benton, Walyara) on large intervening shelves; occurs in association with other 2, 3 and 4 land units within broad clay plains or adjoining stream frontage areas; depressions inundated seasonally. Variable vegetation.	<ul style="list-style-type: none"> • Weaber Plain • Lower Weaber - Keep Plains
4b	Cracking clays (Cununurra) in medium-sized depressions, various other soils (Keep, Benton) on medium intervening shelves and mounds; occurs in association with other 2, 3 and 4 land units within broad clay plains or adjoining stream frontage areas; depressions inundated seasonally. Variable vegetation.	<ul style="list-style-type: none"> • Weaber Plain
4c	Brownish cracking clays with carbonate nodules and high pH topsoils (Keep normal phase, minor Cununurra) mainly on gilgai mounds, other cracking clays (Cununurra) in some depressions; occurs within broad clay plains, sometimes in association with other 2, 3 and 4 land units or adjoining stream frontage areas; gilgais inundated seasonally. Usually treeless.	<ul style="list-style-type: none"> • Ivanhoe Plain • Weaber Plain • Lower Weaber - Keep Plains
4d	Cracking clays with hydromorphic attributes (Cununurra wetter phase, Mottled clays) in depressions, cracking clay intergrades (Milligan) on broad shelves; occurs in seasonally swampy areas at the junction between broad clay plains and sandy or lateritic land systems, but only depressions are inundated. <i>Eucalyptus papuana</i> open woodland.	<ul style="list-style-type: none"> • Weaber Plain • Lower Weaber - Keep Plains
4e	Cracking clays with hydromorphic attributes and high topsoil pH (Keep flooded phase) strongly gilgaied; occurs in seasonally swampy areas, but only gilgai depressions are inundated. Dense woodland.	<ul style="list-style-type: none"> • Weaber Plain • Lower Weaber - Keep Plains

Unit	Description	Survey
4f	Cracking clays (Cununurra, usually alkaline phase) and Red Earths (Weaber) with some intergrades; occurs around areas of units 2c and 2e, but sometimes separately; not yet observed in undeveloped condition.	• Ivanhoe Plain
5a	Cracking clays with hydromorphic attributes (Aquitaine bluish phase, minor Keep flooded phase); occurs in broad low-lying areas, usually where the clay plains adjoin sandy or lateritic land systems; seasonally inundated to moderate depths for long periods. Thick <i>Eucalyptus microtheca/Excoecaria parvifolia</i> woodland.	• Ivanhoe Plain • Weaber Plain • Lower Weaber - Keep Plains
5at	As for 5a but vegetation dominated by species other than <i>Eucalyptus microtheca</i> and <i>Excoecaria parviflora</i> .	• Weaber Plain
5b	Cracking clays with hydromorphic attributes (Aquitaine greyish phase); occurs in broad low-lying areas of the clay plains, often near land unit 5a; seasonally inundated to shallow depths for short periods. Open <i>Eucalyptus microtheca/Excoecaria parvifolia</i> woodland.	• Ivanhoe West Bank • Ivanhoe Plain • Weaber Plain • Lower Weaber - Keep Plains • Knox Creek Plain
5bt	As for 5b but vegetation dominated by species other than <i>Eucalyptus microtheca</i> and <i>Excoecaria parvifolia</i> .	• Weaber Plain
5c	Cracking clays with very hydromorphic attributes (Aquitaine bluish phase) with debil-debil microrelief and inclusions of stone and rock; occurs in depressed linear zones marginal to 5a and immediately adjacent to sandy or lateritic land systems; seasonally inundated to significant depths for long periods. Treeless.	• Ivanhoe Plain • Weaber Plain • Lower Weaber - Keep Plains
5d	Cracking clays with reduced internal drainage capacity (Cununurra wetter phase); occurs within broad cracking clay plains; seasonally waterlogged. Usually treeless.	• Ivanhoe Plain • Weaber Plain
5e	Grey cracking clays of variable depth over limestone.	• Knox Creek Plain
6	Small steep hills and outcrops of sandstone and other rocks in a matrix of stony cracking clays; random occurrence. Varied vegetation.	• Weaber Plain • Lower Weaber - Keep Plains
6a	Greater than 50% silicified sandstone in clay matrix.	• Weaber Plain

Unit	Description	Survey
6b	Sandstone outcrops with associated sandy colluvial aprons.	• Knox Creek Plain
6c	Undifferentiated rock outcrop.	• Ivanhoe West Bank
6d	Dolomitic rock outcrops.	• Weaber Plain
6e	Variable soils, often sandy, over sandy limestone; some rock outcrop.	• Knox Creek Plain
7a	Rivers and major creeks with associated steep banks. Frontage vegetation.	• Ivanhoe Plain • Weaber Plain • Lower Weaber - Keep Plains • Knox Creek Plain
7b	Cracking clays in severely eroded and truncated conditions (Cununurra eroded phase) and other soils bordering and rivers and major creeks; minor levees, point-bars and swamps. Predominantly <i>Lysiphyllum cunninghamii</i> woodland.	• Ivanhoe Plain • Weaber Plain • Lower Weaber - Keep Plains • Knox Creek Plain
7b1	Levees and back plains to Keep River.	• Knox Creek Plain
7c	Flat to gently undulating levee plain; red/brown fine sandy to loamy alluvial soils.	• Ivanhoe West Bank
7d	Recent sand and gravel/stone river deposits - seasonally inundated.	• Ivanhoe West Bank
7e	Slopes of eroded levee, lower terraces, rare rock outcrop near river; occasionally inundated; variable fine sandy to loamy soils.	• Ivanhoe West Bank
7f	Remnant levees of prior streams.	• Knox Creek Plain
8	Undifferentiated complex of units 8a and 8b.	• Weaber Plain
8a	Complex, depressed peripheral zones adjoining unit 8b at sandy or lateritic land systems; soils very variable, but mainly heavy clays with sand inclusions; depressions are seasonally inundated. <i>Eucalyptus microtheca</i> dominated woodland, some <i>Excoecaria parvifolia</i> .	• Weaber Plain
8b	Complex zone between unit 8a and Sandy Land System; soils very variable, mostly duplex. Variable woodland with <i>Eucalyptus polycarpa</i> and <i>E. microtheca</i> .	• Weaber Plain

Unit	Description	Survey
9a	About 40% gradational calcareous clays (Walyara) in a matrix of unit 1a (brownish cracking clays) with finely structured high pH topsoils - Cununurra alkaline phase). Vegetation relatively thick and includes <i>Lysiphyllum cunninghamii</i> , <i>Carissa lanceolata</i> and occasional eucalypts.	• Ivanhoe Plain
9b	About 20% gradational calcareous clays (Walyara) in a matrix with 1a (brownish cracking clays with finely structured high pH topsoils - Cununurra alkaline phase). Vegetation includes <i>Lysiphyllum cunninghamii</i> and <i>Carissa lanceolata</i> .	• Ivanhoe Plain
9c	Brownish cracking clays with finely structured high pH topsoils (Cununurra alkaline phase) and intergrades with Walyara; about 2% gradational calcareous clays (Walyara). Vegetation includes <i>Lysiphyllum cunninghamii</i> and <i>Carissa lanceolata</i> .	• Ivanhoe Plain • Weaber Plain
10a	Cracking clays (Cununurra leached phase) with considerable coarse sand throughout and reduced moisture-holding capacity; possibly old stream bed areas; often underlain by sand.	• Ivanhoe Plain
10b	Cracking clays (Cununurra leached phase) with a little coarse sand and slightly reduced moisture-holding capacity; some intergrades with Weaber soils.	• Ivanhoe Plain • Weaber Plain
11	Colluvial outwash slopes below the sandstone hills; variable soils, often sands or sands over mottled clays (part of Cockatoo Land System).	• Ivanhoe West Bank • Knox Creek Plain
11b	Slopes with Cockatoo sands.	• Knox Creek Plain
B/s	Billabongs or swamps.	• Weaber Plain
Cc	Cockatoo Land System.	• Weaber Plain
L	Lagoon - permanent water.	• Ivanhoe West Bank
Sw	Depressions/swamps; variable, usually clayey soils.	• Ivanhoe West Bank

* Now recognised as non-calcic brown soils.

Appendix 2 Site locations and occurrence in map units

Site	Map unit	Easting	Northing
1	7c	464672	8263708
2	11	464532	8263870
3	2f	464419	8264635
4	2f	466367	8268980
5	7c	466417	8272729
6	7c	466426	8271444
7	7c	468235	8267748
8	2f	467104	8267296
9	7c	466979	8266714
10	7c	466893	8266820
11	7c	466745	8266595
12	7c	466840	8266965
13	1	466615	8266888
14	1	466140	8266967
15	11	465705	8271246
16	1	465882	8271296
17	2g	466000	8270000
18	2f	466498	8269797
19	7c	465952	8273218
20	7c	465861	8273286
21	5b	465856	8272908
22	7c	466164	8272668
23	2f	466029	8271963
24	2f	466039	8271658
25	2f	466088	8271462
26	2f	466216	8271334
27	2f	466134	8270999
28	2g	466167	8270805
29	1	465770	8270822
30	1	466107	8267829
31	1	466237	8268038
32	2f	466071	8268014
33	5b	466883	8267314
34	7c	467355	8267066
35	7c	467455	8266863
36	7c	467952	8268545
37	7c	467369	8268415
38	2f	467145	8268200
39	5b	466881	8268530
40	7c	464634	8262999
41	7e	464797	8262730
42	2f	464395	8262546

43	5b	464289	8262713
44	5b	464452	8263584
45	2f	465080	8265379
46	7c	466350	8265709
47	1	466422	8266081
48	1	466271	8266426
49	2f	465717	8265808
50	11	465247	8268638

Appendix 3. Vegetation list

Botanical name

Acacia farnesiana
Adansonia gregoria
Aristida latifolia
Astrebla squarrosa
Eucalyptus confertiflora
Eucalyptus microtheca
Ficus coronulata
Heteropogon contortus
Iseilema vaginiflorum
Lysiphyllum cunninghamii
Themeda triandra
Whiteochloa airoides
(formerly *Panicum cymbiforme*)

Common name

Mimosa bush
Boab, baobab
feathertop wiregrass
bull Mitchell grass
roughleaf cabbage gum
flooded box
river fig, peach-leaf fig
black or bunch speargrass
red Flinders grass
bauhinia
kangaroo grass
creeping panic

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SOILS OF THE IVANHOE WEST BANK KUNUNURRA WESTERN AUSTRALIA

Noel Schoknecht and Chris Grose
Agriculture Western Australia

Map unit names have been selected to conform with the common map key for the entire Ord Irrigation Area (Aldrick *et al.* 1990), and hence numerical designations may not be consecutive.

- 1** Flat to very gently undulating cracking clay soil plain.
Grey and brown cracking clays - Cununurra normal phase (locally known as "Black Soil")
- 2f** Almost flat red soil plain.
Red soils, usually loams or clay loams over clay (duplex). Hardsetting, and often bare, surface.
- 2g** Dissected red soil and levee plain. Some areas of active erosion.
Variable soils, often with red clayey subsoil exposed.
- 2h** Active erosion, inhospitable subsoils high in carbonates exposed.
- 5b** Flat plain with cracking clays with hydromorphic attributes. Seasonally inundated to shallow depths for short periods.
Grey cracking clay - Aquitaine greyish phase (locally known as "Black soil")
- 6e** Rock outcrop.
- 7c** Flat to gently undulating levee plain.
Red/brown fine sandy to loamy alluvial soils.
- 7d** Recent sand and gravel/stone river deposits - seasonally inundated
- 7e** Slopes of eroded levee, lower terraces, rare rock outcrop near river - occasionally inundated.
Variable fine sandy to loamy soils.
- 11** Colluvial outwash slopes below the sandstone hills.
Variable soils - often sands or sands over mottled clays (Part of Cockatoo Land System).
- L** Lagoon - permanent water
- Sw** Depressions/swamps
Variable, but usually clayey, soils

- Soil Mapping Unit Boundary
- Sealed Road
- - - Unsealed Road
- Vehicular Track
- Fence
- River/Stream
- Irrigation Channel
- Contours (20 m interval)

Acknowledgements

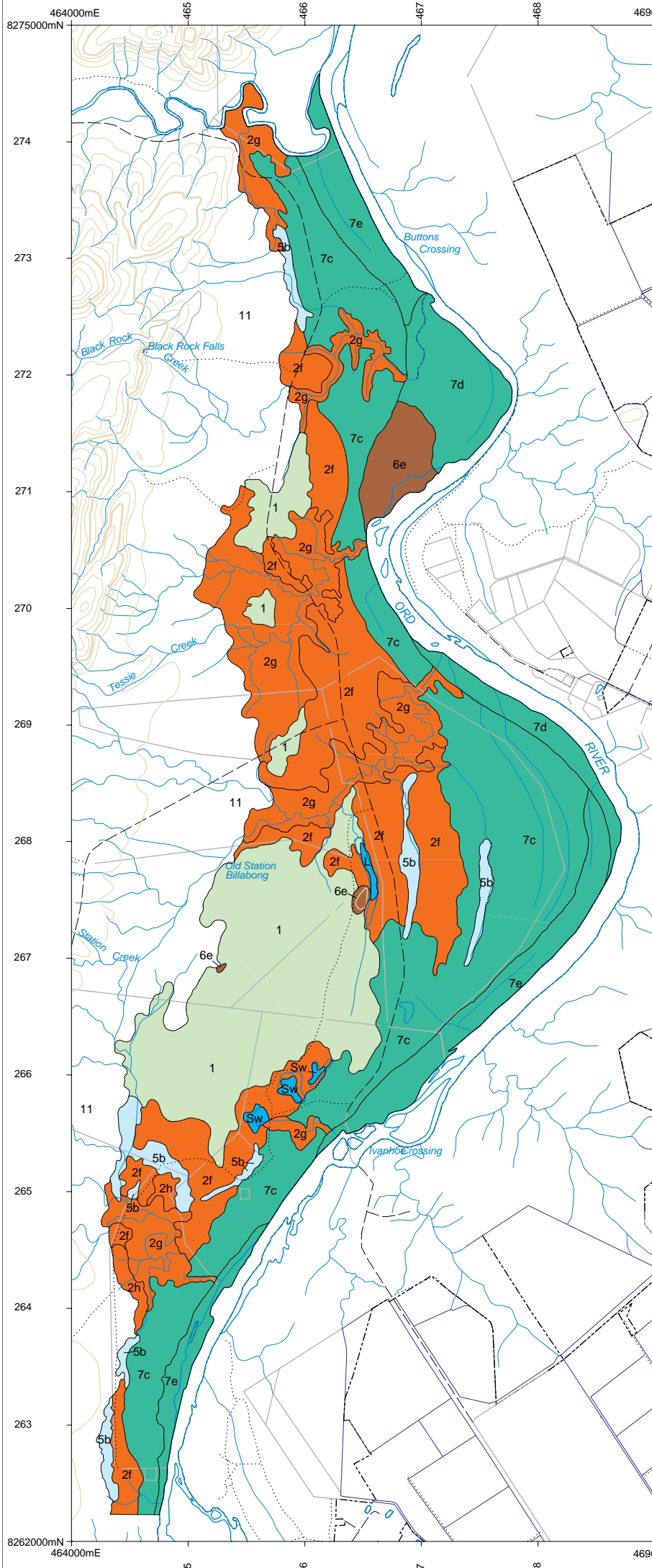
Soil survey by N. Schoknecht and C. Grose, Natural Resources Assessment Group, Agriculture Western Australia. Digital topographic base supplied by the Department of Land Administration. Map prepared by P.M. Goulding, Agriculture Western Australia.

Reference

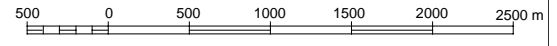
Projection: Universal Transverse Mercator
Grid: AMG zone 52
Source data: Field survey and interpretation of aerial photography.
Aerial photography: WA 3242 (C), 1:20,000, Jul. 1993

Use of map

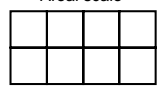
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Scale 1:50 000



Areal scale



40 ha in units of 5 ha



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