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# Soils of the Knox Creek Plain East Kimberley Western Australia and Northern Territory

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*by Noel Schoknecht and Chris Grose*

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**RESOURCE MANAGEMENT TECHNICAL REPORT 153**

# Summary

An assessment of the soils and landforms of approximately 12,000 ha in the Knox Creek Plain in Western Australia and the Northern Territory was conducted in May and June 1994. Seventeen map units were identified and their soils, landform and vegetation characteristics were described.

Grey or brown cracking clays predominate on the plain, however variable red or brown soils on the coarser alluvium of remnant levees are common in the south and south-east.

About 8,000 ha were considered, on the basis of soils and landform only, to be suitable for flood irrigation. Some of the map units considered suitable occur in small areas near units rated either marginally suitable or unsuitable. It is therefore likely that the total area which could be used for flood irrigation is significantly less than 8,000 ha.

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## Map Back pocket

# 1. Introduction

The Ord Development Council (ODC) requested the Department of Agriculture to provide basic soil and landscape information for assessment of the suitability of part of the Knox Creek Plain for irrigated agriculture, and to assist planning for possible expansion of the Ord River Irrigation Area (ORIA).

The area covers approximately 12,000 ha, 30 km north-east of Kununurra. It includes the plain between Knox Creek, Western Australia, and the Keep River, Western Australia and Northern Territory. For the purposes of this study it is known as the Knox Creek Plain.

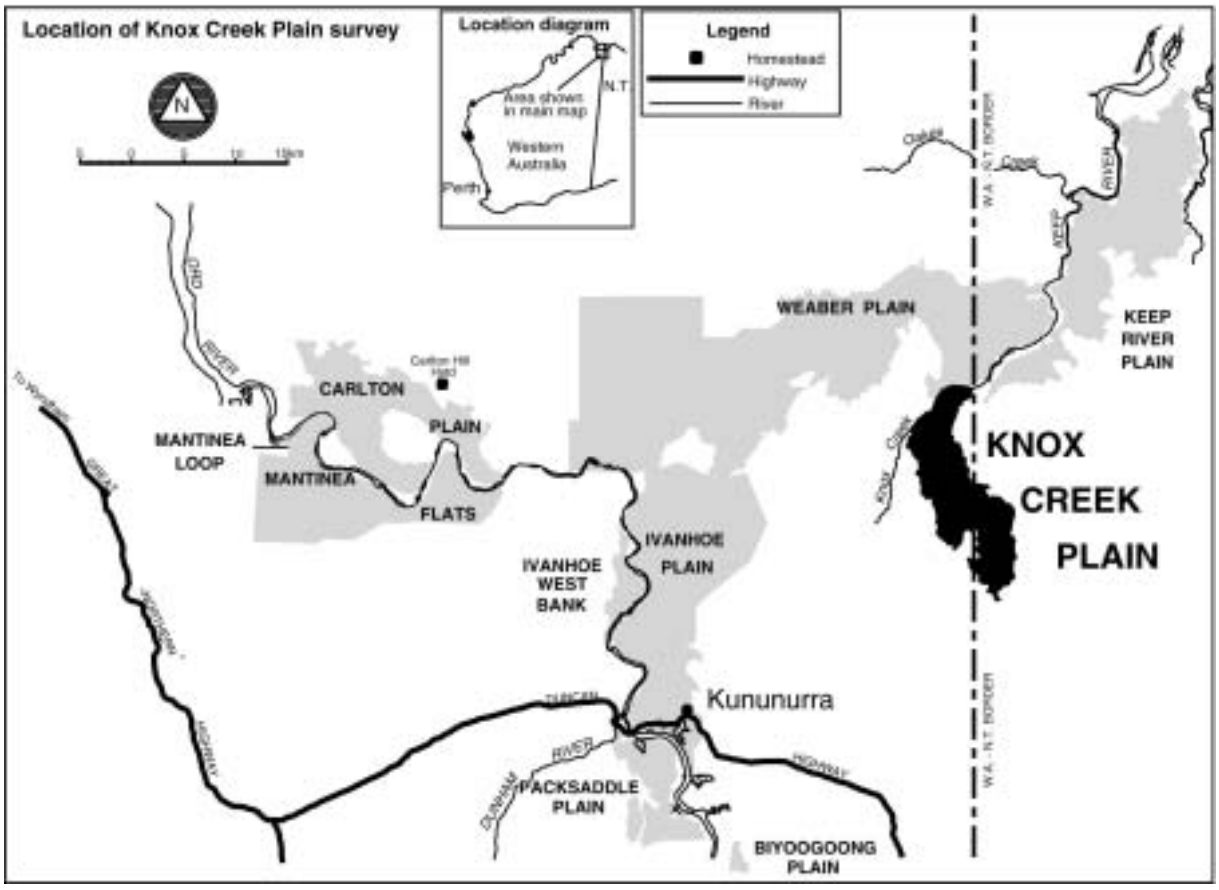


*Figure 1. Location of the Knox Creek Plain in relation to other potential irrigation areas in the Ord River area.*

# 2. History of land use

The study area is presently within Ivanhoe (WA) and Spirit Hill (NT) Stations and is used for grazing of cattle (Brahman, Shorthorn and Brahman-Shorthorn cross) on native grasslands and woodlands. It was first settled by Europeans for such purposes in the 1880s.

# 3. Climate

The area is semi-arid with summer monsoonal rains. Average rainfall for Kununurra (30 km away) is 778 mm, most of which falls in the four months December to March, with a virtual drought for the rest of the year. The mean maximum temperatures range from 30.5°C in July to 38.8°C in November and mean minima range from 14.2°C in July to 24.8°C in December. The area is virtually frost-free (Delane 1987).

*Author Noel Schoknecht enjoys the view from one of the low rocky hills in the Knox Creek Plain.*

# 4. Geology and physiography

The Knox Creek Plain is composed of Quaternary alluvia (Czb - Black soil on the 1:250,000 Cambridge Gulf Geology map). Fluvial sands and gravel (produced by river action) up to 30 m thick exist within a possible paleochannel in the east of the plain. Fine textured sediments dominate other areas. Rocky hills comprised of siliceous siltstone and fine grained sandstone bound the plain on the west (Pincombe Range), and the Keep River forms the eastern boundary.

Interpreted bedrock under the Knox Creek Plain is westerly dipping carboniferous limestone, overlain by carboniferous shale in the east at a depth of about 30 m beneath the level of the plain at the Keep River. Permian conglomeratic sandstone outcrops in the south-east and is possibly underlain by the older shale and limestone (Nixon 1994). Sandy colluvial slopes over sandstone, shale and limestone occur to the south, with occasional outcrops of these rocks within and south of the plain.

*A backhoe was used to dig pits to photograph and sample representative soils. Difficulty was experienced in crossing the uneven and hummocky cracking clay plains.*

# 5. Native vegetation

The native vegetation communities are predominantly savannas comprising a tussock grassland understorey and scattered shrub or tree overstorey (Beard 1990). Four main communities have been identified for the study area and are detailed in Appendix 2. Plant names are from Wheeler *et al.* (1992).

## *Tall tussock grass savanna*

This occurs on grey and brown cracking clays of the Knox Creek alluvial plain. It consists of tall tussock grasses to about 1 m, with trees or shrubs absent or very widely scattered. Common grasses include *Aristida latifolia* (feathertop wiregrass), *Astrebla squarrosa* (bull Mitchell grass), *Chrysopogon fallax* (ribbon grass), *Dichanthium* spp. (blue grasses) and *Iseilema vaginiflorum* (red Flinders grass). Occasional trees or shrubs include *Acacia farnesiana* (mimosa bush), *Atalaya hemiglauca* (whitewood), *Lysiphyllum cunninghamii* (bauhinia), *Teminalia volucris* (rosewood) and *Excoecaria parvifolia* (guttapercha).

## *Tall tussock grass shrub or tree savanna*

This community occurs on grey and brown cracking clays of the Knox Creek alluvial plain. It consists of tall tussock grasses to about 1 m, and a light to sparse tree or shrub overstorey about 4 to 8 m high.

The main tree and shrub species include *Lysiphyllum cunninghamii* (bauhinia), *Eucalyptus microtheca* (flooded box), *Atalaya hemiglauca* (whitewood) and *Terminalia volucris* (rosewood). *Excoecaria parvifolia* (guttapercha) is also common, but tends to occur more frequently in wetter areas, especially shallow drainage lines. Less common trees and shrubs include *Terminalia platyptera* (wing-seed terminalia), *Acacia farnesiana* (mimosa bush) and *Acacia* sp. *H*.

Common grasses include *Aristida latifolia* (feathertop wiregrass), *Astrebla squarrosa* (bull Mitchell grass), *Chrysopogon fallax* (ribbon grass), *Dichanthium* spp. (blue grasses) and *Iseilema vaginiflorum* (red Flinders grass).

## *Open woodland*

Open woodland occurs on sandier soils within the plain. This usually occupies the remnant sandy levees of creeks or rivers which once crossed the plain, the major levee banks beside the Keep River or the colluvial slopes below the hills on the edge of the plain.

Common trees of the remnant levees include *Eucalyptus papuana* (ghost gum) and *Eucalyptus microtheca* (flooded box). The main understorey grass is *Themeda triandra* (kangaroo grass). The slopes surrounding the plain support *Eucalyptus microtheca* (flooded box), *Eucalyptus tectifica* (grey box), *Eucalyptus confertiflora* (roughleaf cabbage gum) and many others.

### *High grass savanna*

High grass savanna dominated by *Sorghum* species occurs on the seasonally waterlogged zones between the cracking clay plain and the sandy colluvial slopes of the sandstone hills. The community is not widespread in the study area.

# 6. Survey procedure

## Previous surveys

The first survey of the area was a reconnaissance of about 300,000 ha between Wyndham and the Western Australian border conducted by Burvill in 1944 (Burvill 1991). This survey was to identify areas with potential for irrigated agriculture. The Knox Creek Plain was identified as having potential, but no soils information was gathered.

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

The soils of the adjacent lower Weaber Plain and Keep Plains in the Northern Territory were described by Aldrick and Moody in 1977.

The soils of the nearby Weaber Plain, Western Australia, were described by Dixon (fieldwork 1977, publication 1996).

## Knox Creek Plain 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 in Western Australia was conducted by Noel Schoknecht and Chris Grose during May and June 1994. Dennis Fett and Stephen Johnston surveyed the Northern Territory component in late June 1994.

In total, 168 complete profiles were described - 138 in WA (about one site per 57 ha) and 30 in the Northern Territory (about one site per 140 ha). The survey of the WA component was more intensive. The profiles were obtained by pushing a 50 mm steel tube down to about 100 to 120 cm with a Gemco drill rig. At selected sites further augering to 300 cm was conducted.

Each profile was examined for a minimum of texture, colour, structure, depth of horizons, pH and electrical conductivity (EC). Ten pits in WA were dug and samples taken for chemical and physical analysis (see Appendix 3). 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 of the area, information from previous surveys and discussions with Kununurra Department of Agriculture staff, soils were described, map units delineated and assessments made.

# 7. Map units

A common map key to link the units throughout all surveys of the Ord River Irrigation Area has been created, based primarily on the land units identified by Aldrick and Moody 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, Mantinea Loop and the Knox Creek Plain. Not all land units of the common key occur within this survey area and thus designations in this survey are not necessarily consecutive. The common map key for the ORIA is in Appendix 4.

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

The units identified on the Knox Creek Plain are:

## *1c Brownish cracking clays: northern parts of the plain*

This unit dominates the north of the Knox Creek Plain. It is a flat to very gently sloping plain occasionally traversed by very minor depressions or flow pathways. Major depressions have been separated out in unit 1e. The soils are mainly brown cracking clays with a weakly self-mulching surface, carbonates in the B horizon and gypsum crystals frequent below 1 m (**Cununurra clay leached brown phase** and **Cununurra clay leached brown-gypsic phase**). The subdominant soil is similar, but grey in colour (**Cununurra clay leached grey phase** and **Cununurra clay leached grey-gypsic phase**).

The native vegetation is mainly tall tussock grass shrub or tree savanna. Common tree or shrub species include *Excoecaria parviflora, Atalaya hemiglauca, Eucalyptus microtheca,* and *Lysiphyllum cunninghamii.* Common grasses include *Aristida latifolia, Chrysopogon fallax, Iseilema vaginiflorum* and *Panicum decompositum.*

See sites KNX129, KNX130 in Appendix 3.

## *1d Greyish cracking clays: southern parts of the plain*

This unit dominates in the south of the Knox Creek Plain in WA, and the north-west of the Northern Territory component. It is a flat to very gently sloping plain which is occasionally traversed by very minor depressions or flow pathways. Major depressions have been separated out in unit 1e. This is very similar to 1c, but with greyer clays.

The soils are mainly grey cracking clays with a weakly self-mulching surface, carbonates in the B horizon and frequent gypsum crystals below 1 m (**Cununurra clay leached grey phase** and **Cununurra clay leached grey-gypsic phase**). The subdominant soil is similar, but

brown in colour (**Cununurra clay leached brown phase** and **Cununurra clay leached brown-gypsic phase**).

The native vegetation is mainly tall tussock grass shrub or tree savanna. Common tree or shrub species include *Eucalyptus microtheca, Excoecaria parviflora, Atalaya hemiglauca, Lysiphyllum cunninghamii, Terminalia volucris and Acacia* sp. *H*. Common grasses include *Aristida latifolia, Chrysopogon fallax, Iseilema vaginiflorum, Dichanthium* spp. and *Astrebla squarrosa.*

See sites KNX133, KNX135 and KNX138 in Appendix 3.

## *1ds As for 1d, but with a stony surface*

This unit is similar to 1d, however the surface is covered with up to 50% (commonly 10 to 30%) rounded stones, from 50 to 200 mm in diameter. The probable source of these stones is weathered Permian conglomerate. Conglomerate containing similar stones was found outcropping near Mulligan's Lagoon in the Northern Territory, and drilling by the Department of Minerals and Energy in 1994 also intersected partially weathered conglomerate below the alluvium of Knox Creek Plain. The stones appear to be concentrated on the surface, and were not observed throughout the soil profile. It is possible that the shrinking and swelling of the grey clays has brought the stones to the surface where the weathered conglomerate is near the surface. It appears that these stones could be easily removed and the soils are expected to perform similarly to those in unit 1d.

See KNX134 in Appendix 3.

## *1e Channels and depressions in cracking clay plain*

This includes flat to very gently sloping depressions which provide flow paths for drainage water. The depressions may be incised by a narrow drainage line, or just broad depression which carry or hold water in the wet season. The soils are typically grey or brown cracking clays **(Cununurra clay leached brown, leached brown-gypsic, leached grey** and **leached grey-gypsic phases)**. The soil surface may be self-mulching, pedal or crusting. The unit appears to be preferred grazing by cattle and the soil surface is often bare and pugged. The pugging may be attributable to the longer wet periods on this unit.

Vegetation is tall tussock grass tree savanna, with *Excoecaria parviflora* and *Eucalyptus microtheca* the dominant trees. Common understorey species include *Chrysopogon fallax, Aristida sp., Sida* spp., *Cyperus cunninghamii* and *Iseilema vaginiflorum*.

## *1f Cracking clay plain with complex pattern of minor levee remnants*

Unit 1f occurs in areas dominated by the grey clays of 1d, but which have numerous traces of remnant stream levees too small to map separately into 7f. Soils and vegetation are very similar to map unit 1d, however intergrades with the soils of unit 7f also occur. *Eucalyptus papuana* may also be present in addition to the vegetation typical of unit 1d.

## 1g Grey cracking clays with self-mulching surface

Occurs in the south of the plain close to areas of unit 7f. Soils are mainly grey cracking clays with self-mulching surface, carbonate and manganese nodules in the B2 horizon and gypsum crystals at depth. Lesser areas occur with brown mottling at depth. These soils are typically Cununurra clay leached grey phase and Cununurra clay normal phase.

Native vegetation is grassland with isolated trees. Common grass is *Chrysopogon fallax* with some areas of *Aristida, Iseileima* and *Sesbania* sp. throughout the unit. Isolated trees include *Eucalyptus microtheca* and *Lysiphyllum cunninghamii.*

See sites KNX131, KNX136 in Appendix 3.

## 5b Cracking clays with hydromorphic attributes: low-lying areas

These occur in the flatter parts of the plain. They are seasonally inundated and have many small stream channels joining the areas of gilgai. Soils are cracking clays, typically Aquitaine greyish phase.

Native vegetation is an open woodland with dense grasses. Dominant trees and shrubs include *Lysiphyllum cunninghamii*, *Excoecaria parviflora*, *Acacia* sp. and *Terminalia volucris*. Dominant grasses include *Chrysopogon fallax, Iseileima* sp. and sedges of *Fimbristylis* sp. with *Sesbania* sp.

## 5e Grey cracking clays of variable depth over limestone

This unit is flat to gently sloping plain with variable grey clayey soils over limestone. Soil depth is extremely variable and bands of limestone outcrop are common. A pronounced gilgai microrelief is common in some areas. The soils are typically pale grey or grey sandy or silty clay loams at the surface, grading to or over grey light to medium clays. The subsoil pH is usually high and often higher than 9.0. Rotting limestone bedrock may be encountered by 50 cm, and limestone fragments are common through the lower soil profiles. Rootline mottling is common in the surface horizon indicating seasonal waterlogging. A surface crust is common. The surface soil is likely to be spewy when wet and pugging is common.

## 6b Sandstone outcrops associated with steep banks

This includes sandstone outcrops with associated sandy colluvial aprons.

## 6e Variable soils, often sandy, over sandy limestone; some rock outcrop

Gently undulating rises with variable red, brown or yellow soils, often sandy, occur on sandy limestone in the south-west of the study area. Occasional rock outcrops in bands on the rises. The native vegetation is an open woodland including roughleaf cabbage gum (*Eucalyptus confertiflora*), *Acacia dunnii, Cochlospermum fraseri* and mixed grasses.

## 7a Rivers and major creeks with associated steep banks

Major rivers and creeks and associated steep and sometimes eroded banks. Soils are variable, but often eroded Cununurra cracking clays (grey and brown), and sandy or loamy levee soils. Frontage vegetation includes trees such as *Eucalyptus papuana, E. microtheca* and *Lysiphyllum cunninghamii,* with *Melaleuca* spp. along channels.

## 7b Cracking clays in eroded and truncated condition and other soils bordering rivers and major creeks

Sloping margins of the plains immediately adjacent to the major river and creek banks; severe natural erosion. Variable soils, often cracking clays which have been eroded and truncated.

## 7b1 Levees and backplains of the Keep River

Levees and backplains of the Keep River in the Northern Territory. Soils are cracking and non-cracking clays (grey and brown), hardsetting, with no gilgai microrelief present. Surface soil is light clay with some fine sand and mottling at depth.

The native vegetation consists of a grassland with scattered to open woodland. Grasses include *Chrysopogon fallax, Iseilema vaginiflorum* and *Sorghum* spp. Trees and shrubs include *E. microtheca, L. cunninghamii* and occasionally *E. papuana* and *Carissa lanceolata*.

## 7f Remnant levees of prior streams; variable, often sandy soils

The south of the Knox Creek Plain is traversed by numerous prior stream levees which have been partly or fully buried by clayey alluvium. It is often possible to trace these levees for considerable distances across the plain where their presence may be indicated by a line of trees following the levee trace. The levees are usually flat, at the same level as the surrounding clay plain, and often very narrow, sometimes less than 10 m wide. They are much more developed in the far south-east of the plain in the Northern Territory.

The soils are variable, ranging from brown to red, with sandy or loamy surface soils changing gradually or rapidly to clay by 20 cm. The subsoil is often well structured but may be massive and apedal. Coarser sands sometimes occur below the clay subsoil.

The native vegetation is an open woodland with *Eucalyptus papuana, Eucalyptus microtheca* and *Lysiphyllum cunninghamii* common. The many grassy understorey species include *Themeda triandra* and *Sporobolus australasicus*.

See KNX132, KNX137 in Appendix 3.

### 8a Complex, depressed peripheral zones adjoining sandy or lateritic systems; variable soils, mainly heavy clays with sand inclusions; depressions seasonally inundated

This unit occurs as a narrow low-lying strip along the edge of the clay plain near the sandy land systems. It is part of what was called the 'junction complex' by Burvill (1990). This area receives run-off and seepage water from both the clay plain and the sandy areas, and depressions are seasonally inundated. Soils are very variable, but are often yellow/brown cracking clays or hardsetting loams over mottled yellow or brown clays. The vegetation is usually open woodland including *Eucalyptus microtheca*, *Excoecaria parvifolia* and *Eucalyptus tectifica*. *Themeda triandra* is a common understorey grass.

### 11 Colluvial outwash slopes below the sandstone hills; variable soils, often sands or sands over mottled clays

The unit describes in general terms the broad, gently sloping outwash fans from the sandstone hills surrounding the Knox Creek Plain. Soils are variable, but often hardsetting sands or loams over mottled yellowish clays. The vegetation is primarily an open woodland with *Eucalyptus tectifica*, *Eucalyptus confertiflora* and *Adansonia gregorii*. Understorey grasses include *Themeda triandra* and *Sorghum* sp.

### 11b Slopes with Cockatoo sands

This describes small areas of gentle slopes (generally <5%) with Cockatoo sands flanking the hills in the south of the study area. The typical Cockatoo sand observed in the study area is an apedal reddish brown loamy sand grading to red clayey sand at depth. Native vegetation is open woodland with *Eucalyptus tectifica* and *Adansonia gregorii*.

### L Lagoons

Lagoons or billabongs containing permanent water. Their size will expand and contract during the wet and dry seasons.

# 8. Soils

Where possible the soil names from Riley *et al.* (1993) have been used, with modification or addition to suit the range of soils on the study area. The main soils occurring in the study area are described.

## Cununurra family (Cununurra cracking clays)

The Cununurra clays include most of the soils in the ORIA. Previous surveys have identified several phases of these soils based on pH, colour, drainage and degree of erosion (Aldrick *et al.* 1990, Burvill 1991, Dixon 1996). The Cununurra clays identified within the ORIA by these authors are compared in Table 1.

*Cracking clay soils dominate the study area. This Cununurra clay leached brown gypsic phase occurred at site KNX130 in Western Australia.*

**Table 1. Comparison of Cununurra clays in different parts of the Ord River Irrigation Area.**

| Cununurra clay phase | Survey | Key properties |
|---|---|---|
| Normal | • Burvill<br>• Ivanhoe Plain<br>• Lower Weaber and Keep Plains<br>• Weaber Plain | ♦ Main colour dark (V/C=1)<br>♦ Topsoil tilth medium<br>♦ Virgin topsoil pH 7.5 to 8.0<br>♦ Some carbonates in upper profile, increasing with depth<br>♦ Drainage poor |
| Alkaline | • Ivanhoe Plain<br>• Weaber Plain | ♦ Main colour brown (V/C=5)<br>♦ Topsoil tilth fine<br>♦ Virgin topsoil pH 7.8 to 8.5<br>♦ Carbonates present throughout, including surface<br>♦ Drainage imperfect to poor |
| Leached | • Ivanhoe Plain<br>• Weaber Plain | ♦ Main colour grey (V/C=2)<br>♦ Topsoil tilth cloddy<br>♦ Virgin topsoil pH 6.8 to 7.8<br>♦ No carbonates except few low in profile<br>♦ Drainage poor to very poor |
| Eroded | • Burvill<br>• Weaber Plain | ♦ Similar to normal phase but severe gully-erosion<br>♦ Slight to almost total truncation |
| Brown | • Lower Weaber and Keep Plains | ♦ Browner than normal phase<br>♦ Supports dense stands of *Lysiphyllum cunninghamii*<br>♦ Possibly shallower and drier |
| Darker | • Lower Weaber and Keep Plains<br>• Weaber | ♦ Similar to normal phase but darker in colour |
| Flooded/<br>Wetter phase | • Burvill<br>• Ivanhoe<br>• Weaber<br>• Lower Weaber and Keep Plains | ♦ Similar to leached phase<br>♦ Upper soil colour grey, subsoil often pale grey<br>♦ Seasonally inundated<br>♦ Very poorly drained<br>♦ Intergrades with Aquitaine soils |

The Cununurra clays of the Knox Creek Plain fit **generally** within the leached, brown and normal phases identified previously. However they do not fit **exactly** within previous descriptions, and new phases were identified and described.

## *1. Cununurra clay leached phase subgroups*

### 1.1 Grey and grey-gypsic phase

Typically these soils have mild gilgai microrelief (10 to 15 cm amplitude and 1 to 3 m spacing) and the profiles are greater than 100 cm deep. The gypsic phase has a lower B horizon with free gypsum crystals of about 2 to 5 mm.

**Simplified grey-gypsic phase profile**

| Horizon | Depth (cm) | Description |
|---|---|---|
| A11 | 0-5 | Dark greyish brown (10YR 4/2) medium clay, strong subangular blocky structure, prominent cracks, pH 7.1, clear boundary. |
| A12 | 5-50 | Dark greyish brown (2.5Y 4/2) medium heavy clay, strong prismatic structure, prominent cracks, occasional manganiferous nodules, pH 7.8, gradual boundary. |
| B21 | 50-140 | Dark greyish brown (10YR 4/2) medium heavy clay, moderate subangular blocky structure, trace of carbonate concretions, occasional manganiferous nodules, pH 8.5, gradual boundary. |
| B22 | 140-200+ | Dark brown (10YR 4/2.5) medium heavy clay, moderate subangular blocky structure, trace of carbonate concretions, some gypsum crystals, pH 7.8. |

Australian Soil Classification: Self-mulching Grey Vertosol
(Isbell 1995) Epipedal Grey Vertosol

See soil profiles KNX130-131, KNX133-136 and KNX138 in Appendix 3.

### 1.2 Brown phase and brown-gypsic phase

These soils are very similar to the grey phase. They have mild gilgai microrelief (10 to 15 cm amplitude and 1 to 3 m spacing) and the profiles are >100 cm deep. They appear to slightly better drained than the grey phase, and are more likely to have a gypsic subsoil. The gypsic phase has a lower B horizon with free gypsum crystals of about 2 to 5 mm. They may fit between the leached and browner phases of Aldrick (1990).

**Simplified brown-gypsic profile** (See KNX129 in Appendix 3)

| Horizon | (cm) | Description |
|---|---|---|
| A11 | 0-7 | Dark brown (10YR 4/3) light medium clay, strong granular structure, pH 6.8, clear boundary. |
| A12 | 7-30 | Dark brown (10YR 4/3) medium clay, strong subangular blocky structure, prominent cracks, traces of carbonate concretions, pH 7.4, gradual boundary. |
| B21 | 30-100 | Dark brown (10YR 4/3) heavy clay, strong subangular blocky structure, prominent cracks, traces of carbonate concretions, pH 8.0, gradual boundary. |
| B22 | 100-180+ | Dark brown (7.5YR 4/3) medium heavy clay, moderate angular blocky structure, some gypsum crystals, pH 7.8. |

| | |
|---|---|
| Australian Soil Classification: | Self-mulching Brown Vertosol |
| (Isbell 1995) | Epipedal Brown Vertosol |

## 2. Cununurra clay normal phase

These soils have mild gilgai microrelief (20 to 25 cm amplitude) and are about 120 to 150 cm deep over reddish parent alluvium (Aldrick 1990). They have higher surface pH than the leached phase and more carbonates throughout the profile. They were not common on the Knox Creek Plain.

**Simplified profile (from Aldrick 1990)**

| Horizon | Depth (cm) | Description |
|---|---|---|
| A11 | 0-5 | Very dark greyish brown (10YR 3/2) self-mulching clay, pH 7.5. |
| A12 | 5-25 | Very dark greyish brown (10YR 3/2) medium to heavy clay, very hard, strongly structured, some carbonates, pH 8.5. |
| A13 (B2) | 25-125 | Very dark greyish brown (10YR 3/2) heavy clay, extremely hard, strongly structured, some carbonates, pH 8.5. |

Australian Soil Classification: Self-mulching Grey Vertosol
(Isbell 1995) Epipedal Grey Vertosol
Aquic Grey Vertosol

## 3. Cununurra clay eroded phase

Soils of this phase are similar to both the normal and brown phases, but are severely gully-eroded. The degree of truncation varies from slight to almost total. They occur in small areas beside the Keep River.

# Aquitaine family

## *Aquitaine greyish phase (Aldrick 1990)*

The soils of this family 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 apart) has developed.

Within the ORIA, several phases of the Aquitaine soils have been identified. The greyish phase, which is only inundated for short periods, was the only one found in the Knox Creek Plain. These soils merge with the Cununurra clay leached grey phases.

**Simplified profile**

| Horizon | Depth (cm) | Description |
|---|---|---|
| A1 | 0-7 | Dark greyish brown (10YR 4/2) light medium clay, strong subangular blocky structure, common fine prominent reddish yellow mottles, pH 6.9, clear boundary. |
| B1 | 7-56 | Dark greyish brown (2.5Y 4/2) medium clay, strong prismatic structure, pH 8.1, gradual boundary. |
| B21 | 56-134 | Dark greyish brown (2.5Y 4/2) medium heavy clay, moderate angular blocky structure, slickensides, occasional calcareous and manganiferous concretions, pH 8.9, gradual boundary. |
| B22 | 134-200+ | Dark yellowish brown (10YR 4/4) medium clay, moderate subangular blocky structure, occasional calcareous and manganiferous concretions, pH 8.6. |

Australian Soil Classification: Self-mulching Grey Vertosol
(Isbell 1995) Epipedal Grey Vertosol
Aquic Grey Vertosol

## Soils of the levee remnants

Using the Australian Soil Classification (Isbell 1995), three main soil groups were identified on the often narrow levee remnants.

The soil colours were typically red or brown. The soils frequently had a sandy loam to sandy clay loam topsoil which graded or changed abruptly into a clayey subsoil. In some cases the subsoils were mottled. In most cases the subsoil was well structured, although some were massive and porous. They were usually slightly acidic on the surface (pH 6.0 to 6.5) grading to neutral (pH 7.0 to 7.5) at depth. In several cases the soils were underlain by lighter textured alluvium. This group of soils can be correlated with the soils of the lower Weaber and Keep Plains (Aldrick and Moody 1977) as shown in Table 2.

**Table 2. Key properties of the soils of the levee remnants.**

| **Australian Soil Classification** | **Soil Family (Aldrick 1977)** | **Key properties** |
|---|---|---|
| Red or Brown Chromosol | Bonaparte | Red or brown colour<br>Texture contrast: lighter topsoil over clayey subsoil<br>Subsoil may be mottled |
| Red or Brown Dermosol | Bonaparte/Weaber | Red or brown colour<br>Gradual increase in texture with depth<br>Structured subsoil |
| Red or Brown Kandosol | Weaber | Red or brown colour<br>Gradual increase in texture with depth<br>Massive (not structured) or weakly structured subsoil |

Typical profiles of these soil groups follow.

### *Red or Brown Chromosol (Bonaparte family)*

| **Horizon** | **Depth** (cm) | **Description** |
|---|---|---|
| A1 | 0-15 | Dark brown (7.5Y 4/2), light sandy clay loam, weak platy structure, porous, pH 6.7, clear boundary. |
| B2 | 15-75 | Yellowish red (5YR 4/6), medium clay, strong prismatic structure, occasional manganiferous concretions, pH 6.5, clear boundary. |
| BC | 75-115 | Yellowish red (5YR 4/6), light sandy clay loam, apedal, massive, pH 6.7, gradual boundary. |
| C | 115-170 | Yellowish red (5YR 4/6), clayey sand, apedal, massive, pH 6.8. |

See KNX132 in Appendix 3.

### *Red or Brown Dermosol (Bonaparte/Weaber family)*

| **Horizon** | **Depth** (cm) | **Description** |
|---|---|---|
| A1 | 0-3 | Dark reddish brown (2.5YR 3/3) loamy sand, apedal and massive, sharp boundary. |
| B1 | 3-13 | Reddish brown (2.5YR 4/4) fine sandy clay loam, moderate subangular structure, clear boundary. |
| B21 | 13-54 | Reddish brown (5YR 4/4) light clay, strong subangular blocky, occasional manganiferous nodules, gradual boundary. |
| B22 | 54-175+ | Yellowish brown (10YR 5/4) sandy light clay, weak subangular blocky structure, moderate fine distinct strong brown (7.5YR 5/6) mottles, manganese staining, occasional manganiferous nodules. |

See KNX137 in Appendix 3.

## Red or Brown Kandosol (Weaber family)

| **Horizon** | **Depth** (cm) | **Description** |
|---|---|---|
| A1 | 0-15 | Dark brown (7.5YR 4/4) very fine sandy clay loam, weak angular blocky structure, pH 8.0, clear boundary. |
| B1 | 15-55 | Reddish brown (5YR 4/4) very fine sandy light clay, weak subangular blocky structure, pH 7.4, gradual boundary. |
| B21 | 55-80+ | Reddish brown (5YR 4/4) sandy clay, weak subangular blocky structure, occasional manganiferous nodules. |

# Minor soils

## *Grey clay soils over limestone*

Pale grey clays over limestone were observed in the south-west of the Knox Creek Plain. Although variable, they were often a silty to sandy clay loam grading, or changing abruptly, to a sandy or medium clay at depth grading into rotting limestone. Limestone fragments were often found throughout the profile and occasionally scattered on the surface. The soils invariably had a surface crust and were pugged indicating seasonal waterlogging and possibly spewy when wet. Red-brown rootline mottling in the topsoil also indicated seasonal waterlogging. The colours were typically pale grey or greyish brown. In areas of deeper clays gilgais were present. The soils were often highly alkaline, with pH of up to 9.9 in the subsoil.

**Typical soil profile**

| Horizon | Depth (cm) | Description |
|---|---|---|
| A11 | 0-3 | Greyish brown (2.5Y 5/2) sandy clay loam, strong fine subangular blocky structure, pH 8.1, clear boundary. |
| A12 | 3-30 | Greyish brown (2.5Y 5/2) light sandy clay, strong subangular blocky structure, pH 8.8, gradual boundary. |
| B | 30-100 | Grey (5Y 5/1) sandy clay, structure not determined, some carbonate concretions, pH 9.1, gradual boundary. |
| BC | 100-120+ | Grey (5Y 5/1) light clay, structure not determined, pH 8.1. |

## *Sands over limestone/sandstone*

Yellow, orange, red and brown sands of variable depth occur over limestone and sandstone in the south of the study area. These soils were not examined in detail. Rock outcrop or surface stones are common.

## *Junction complex soils*

Soils that occur on the junction between the cracking clay plain and the hills of the Cockatoo Land System are extremely variable. The main soil types are soils from the **Milligan family** and **Mottled clays**. These soils are a minor component of the Knox Creek Plain.

**Milligan family** clays are uniform fine-textured clays with significant inclusions of ferruginous gravel and sands from the sandy country nearby. The are not gilgaied soils, but may exhibit some cracking.

The **Mottled clays** are dark cracking clays with significant profile mottling especially in the upper levels. They occur in unit 8a in association with Milligan soils that are seasonally inundated.

## *Cockatoo sands family*

The Cockatoo sands have developed from ferruginous sandstone parent material. Although variable in texture, they are always red, massive and sandy to loamy. Cockatoo sands were encountered in a couple of locations in the south of the study area.

**Typical profile**

| Horizon | Depth (cm) | Description |
|---|---|---|
| A1 | 0-10 | Reddish brown (2.5YR 5/4) loamy sand, apedal and massive, pH 7.6, clear boundary. |
| C | 10-100 | Red (10R 4/8) clayey sand, apedal and massive, pH 8.0. |

# 9. Land use interpretations

## Suitability of map units for flood irrigation

### *Map unit 1c*

This has a relatively uniform range of brown and less commonly grey cracking clays, and is suitable for flood irrigation. Similar soils in the Ivanhoe Plain have proven well suited to a range of crops under flood irrigation. Minor limitations could be the formation of a cloddy topsoil after repeated cultivation. This unit is expected to behave similarly to unit 1d, although the brown cracking clays which predominate here should be slightly better drained than the predominantly grey clays of 1d.

### *Map unit 1d*

This has a relatively uniform range of grey and less commonly brown cracking clays and is well suited to flood irrigation. Similar soils in the Ivanhoe Plain have proven well suited to a range of crops under flood irrigation. Minor limitations to use could be the formation of a cloddy topsoil after repeated cultivation. This map unit is expected to behave similarly to unit 1c, although the grey cracking clays which predominate could be slightly poorer drained than the predominantly brown clays of map unit 1c.

The map unit also contains small remnant stream levees. The larger remnants are shown on the soil map as lines of green dots, however there are also many smaller remnants which were not mapped at the scale of the survey. These levee remnants will have different water infiltration properties to the surrounding cracking clays, and may limit the suitability of some areas for flood irrigation.

### *Map unit 1ds*

The presence of up to 50% stone on the surface would initially limit cultivation. It appears that the stones are concentrated on the surface, and after their removal the map unit would perform similarly to unit 1d. It would be likely however that stones within or below the soil profile could be brought to the surface over time with seasonal cracking and swelling of the clays, and isolated stones which work their way to the surface would cause minor limitation to land use.

### *Map unit 1e*

Soils of this unit are similar to those in units 1c and 1d and are well suited to flood irrigation. However, the unit is the preferred pathway for water moving over the plain, and engineering works would be needed to counter this problem.

### *Map unit 1f*

Soil variability is the main limitation to flood irrigation in this unit. A complex mix of grey cracking clays (dominant) and small remnant levee areas (minor) could cause variability in infiltration of irrigation water.

### *Map unit 1g*

These areas would be suitable for irrigated agriculture.

### *Map unit 5b*

Surface drainage of this unit would be necessary before irrigation could proceed. The soils are poorly drained internally, and if irrigated waterlogging could be a limitation. Experience in the Ivanhoe Plain has shown that these soils can be successfully irrigated. Problems may also occur with poor topsoil tilth.

### *Map unit 5e*

This unit has pale grey clays which are seasonally wet, and have very high subsoil pH (up to 9.9). The topsoils form crusts and show evidence of pugging by stock. The pale grey topsoils are also likely to be spewy when wet. This unit is not considered suitable for irrigated agriculture.

### *Map unit 6b*

This unit, including sandstone rock outcrops and adjacent sandy colluvial aprons, is not suitable for irrigated agriculture.

### *Map unit 6e*

These sandy soils over limestone or sandstone are not suitable for flood irrigation. There may be areas with deep enough soils for spray or trickle irrigation, however insufficient detailed survey work has been conducted in these areas to determine if this option is viable.

### *Map unit 7a*

The channel areas adjacent to the Keep River are not suitable for irrigated agriculture but form an important habitat for wildlife. The Keep River, unlike the Ord River, has no flood control devices, and major flood flows are likely through this unit in the wet season.

### *Map unit 7b*

These are frontage areas and are unsuitable for irrigation. Small areas of levee soils may be suitable for spray or trickle irrigation, however these can be regularly inundated by seasonal flooding of the Keep River and are unlikely to be economically viable.

### *Map unit 7b1*

This unit would be unsuitable for irrigated agriculture. Soils have a lighter surface with fine sand, indicating deposition from over-bank flow. They are very susceptible to erosion as

shown by the major washout on the Keep River. These areas should be kept as a buffer zone to the Keep River.

### *Map unit 7f*

The soils within this unit were very variable. Individually, many soils would be suitable for irrigation, especially spray or trickle irrigation, however the shape of this unit plus the expected variability in permeability of the soils would make irrigation difficult. On this basis the unit has rated marginally suitable for flood irrigation.

### *Map unit 8a*

These are varied areas, with a low capability for irrigated agriculture. Poor drainage, inundation and waterlogging are the main limitations. This map unit would be a suitable location for drainage systems in an irrigation design.

### *Map unit 11*

The soils of the colluvial slopes below the sandstone hills have not been assessed for suitability for irrigated agriculture. Variable soils, variable infiltration rates and sloping relief make them unsuitable for flood irrigation. No assessment has been made of their suitability for spray or trickle irrigation, although brief examinations indicate that they are unsuitable.

### *Map unit 11b*

Cockatoo sands have been used to a limited extent in other parts of the ORIA under spray or trickle irrigation to grow peanuts and other annual and perennial horticultural crops. Because they are well drained, access is possible in the wet season. The Cockatoo sands are very limited in area in the far south-west. These factors may make their use unviable in the short-term.

## Suitability for flood irrigated agriculture

Areas for flood irrigation should be large and relatively flat with a uniform soil type. Total area of each map unit is shown in Table 3 and their suitability for flood irrigation in Table 4.

The northern part of the Knox Creek Plain (unit 1c and parts of 1d) meets the requirements and appears well suited. Areas in the south of the Western Australian part of the plain and the south-east of the plain in the Northern Territory have very variable soils, with red or brown soils of the remnant levees mixed with grey clays of the plain. This variability will restrict the ease of use for flood irrigation as different soils vary in physical and chemical characteristics. Careful irrigation design and the use of spray or trickle irrigation may make such areas suitable.

**Table 3. Total area of each map unit in survey area.**

| Map unit | Western Australia (ha) | Northern Territory (ha) | Total (ha) |
|---|---|---|---|
| **1c** | 2,800 | | 2,800 |
| **1d** | 2,113 | 897 | 3,010 |
| **1ds** | 62 | 25 | 87 |
| **1e** | 113 | 116 | 229 |
| **1e/7f** | 65 | | 65 |
| **1f** | 268 | | 268 |
| **1g** | 412 | 1,080 | 1,492 |
| **5b** | | 451 | 451 |
| **5e** | 191 | | 191 |
| **6b** | 247 | 120 | 367 |
| **6e** | 161 | | 161 |
| **7a** | | 263 | 263 |
| **7a/7b** | 480 | 176 | 656 |
| **7b1** | | 275 | 275 |
| **7f** | 149 | 678 | 827 |
| **8a** | 110 | 25 | 135 |
| **11** | 677 | 50 | 727 |
| **11b** | 50 | | 50 |
| **L** | | 5 | 5 |
| **TOTAL** | 7,898 | 4,161 | 12,059 |

**Table 4. Suitability of map units for flood irrigation.**

| Map unit | Suitability | Limitations |
|---|---|---|
| **1c** | Suitable | Large areas of uniform brown or grey cracking clay |
| **1d** | Suitable | Large areas of uniform grey cracking clay |
| **1ds** | Suitable | Surface rock to be removed |
| **1e** | Suitable | Drainage needs to be provided |
| **1f** | Marginally suitable | Complexity of soil types |
| **1g** | Suitable | Large areas of cracking clay |
| **5b** | Suitable | Surface drainage may be required; some areas may be too small or isolated |
| **5e** | Not suitable | Soils unsuitable |
| **6b** | Unsuitable | Rock outcrop |
| **6e** | Unsuitable | Slopes, sandy soils, rock |
| **7a** | Unsuitable | Proximity to Keep River |
| **7b** | Unsuitable | Eroded and variable soils; close to Keep River |
| **7b1** | Unsuitable | Erodible and close to the Keep River |
| **7f** | Marginally suitable | Very variable soils with variable chemical and physical properties |
| **8a** | Unsuitable | Poorly drained and variable soils |
| **11** | Unsuitable | Slopes, unsuitable sandy or texture contrast soils |
| **11b** | Unsuitable | Slopes and high infiltration rates |
| **L** | Unsuitable | Permanent water |

## Salinity and drainage

One of the major concerns for long-term viability of irrigation in the Knox Creek Plain, and for the rest of the ORIA, is the risk of salinity caused by rising saline groundwater tables. Investigation of the electrical conductivity (EC 1:5 mS/m) of the soils in the Knox Creek Plain showed that under the Cununurra clays it was common to record a rapid rise in subsoil EC below 100 cm. EC values >400 mS/m was frequently recorded. EC data for selected soils are shown in Appendix 6. Initially it was considered that these salts were sodium chloride, however tests of the chloride content of the soil samples indicated that sodium chloride could explain only about 10% of the electrical conductivity. Calcium sulphate (gypsum), which occurred as free crystals in the subsoils, explained about half of the EC reading. The rest is probably sodium and magnesium sulphates (Greg Dellar, Chemistry Centre, pers. comm.).

The EC of samples taken from seven deep holes drilled on the plain by the Hydrogeology Branch of the Department of Minerals and Energy is presented in Appendix 7. The results indicate that although the major concentration of salts is within 3 m of the surface, appreciable salts occur throughout many of the deep profiles.

This finding has serious implications for salinity on the Knox Creek Plain. Sodium chloride and sodium and magnesium sulphates are all highly soluble and would be rapidly mobilised by rising groundwater. It is imperative then that for the long-term sustainability of irrigation on the plain, the movement of groundwater below the soil is understood. If irrigation causes accession of water to the groundwater tables as would be expected, and the groundwater tables do not drain (or are artificially drained) at a sufficient rate, the watertables will rise causing soil salinity.

Successful irrigation of the Knox Creek Plain therefore depends on adequate drainage of groundwaters so that they do not approach the soil surface and cause concentration of salts by capillary action, plus careful application of irrigation water to minimise accession to the groundwaters.

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# Appendix 1. Site locations

Detailed information on sites can be obtained from Natural Resources Assessment, Agriculture Western Australia, South Perth.

Sites KNX001-138 in WA, KN01-30 in NT (All sites in zone 52L).

| Site no. | Easting (m) | Northing (m) |
|---|---|---|
| KNX001 | 499263 | 8286141 |
| KNX002 | 498072 | 8281158 |
| KNX003 | 499950 | 8275841 |
| KNX004 | 497247 | 8286831 |
| KNX005 | 497247 | 8286537 |
| KNX006 | 497322 | 8285976 |
| KNX007 | 497817 | 8285994 |
| KNX008 | 498699 | 8286011 |
| KNX009 | 498144 | 8286841 |
| KNX010 | 496982 | 8286003 |
| KNX011 | 496117 | 8286145 |
| KNX012 | 496147 | 8286081 |
| KNX013 | 496547 | 8286023 |
| KNX014 | 497218 | 8282915 |
| KNX015 | 496787 | 8283196 |
| KNX016 | 496333 | 8283372 |
| KNX017 | 495318 | 8283966 |
| KNX018 | 497092 | 8272476 |
| KNX019 | 497099 | 8273103 |
| KNX020 | 497086 | 8273651 |
| KNX021 | 496838 | 8274287 |
| KNX022 | 496679 | 8274720 |
| KNX023 | 497609 | 8275060 |
| KNX024 | 498353 | 8275068 |
| KNX025 | 498638 | 8274510 |
| KNX026 | 497285 | 8285652 |
| KNX027 | 497228 | 8285201 |
| KNX028 | 496723 | 8285232 |
| KNX029 | 496431 | 8285293 |
| KNX030 | 497297 | 8284552 |
| KNX031 | 497281 | 8283935 |
| KNX032 | 497570 | 8282219 |
| KNX033 | 498582 | 8280073 |
| KNX034 | 499303 | 8278678 |
| KNX035 | 498695 | 8279256 |
| KNX036 | 498420 | 8279038 |
| KNX037 | 498174 | 8278857 |
| KNX038 | 497854 | 8278555 |
| KNX039 | 497424 | 8278258 |
| KNX040 | 496942 | 8277929 |
| KNX041 | 496604 | 8277649 |
| KNX042 | 496240 | 8277349 |
| KNX043 | 495886 | 8277115 |
| KNX044 | 495653 | 8276915 |
| KNX045 | 495353 | 8275765 |
| KNX046 | 495360 | 8276895 |
| KNX047 | 495319 | 8276881 |

| Site no. | Easting (m) | Northing (m) |
|---|---|---|
| KNX048 | 494514 | 8276625 |
| KNX049 | 494413 | 8277145 |
| KNX050 | 494413 | 8277135 |
| KNX051 | 494628 | 8277407 |
| KNX052 | 494153 | 8277613 |
| KNX053 | 495108 | 8278092 |
| KNX054 | 495266 | 8277887 |
| KNX055 | 495905 | 8277876 |
| KNX056 | 497427 | 8278030 |
| KNX057 | 497575 | 8278003 |
| KNX058 | 498008 | 8277648 |
| KNX059 | 498891 | 8277514 |
| KNX060 | 496331 | 8276417 |
| KNX061 | 496926 | 8276772 |
| KNX062 | 497554 | 8276109 |
| KNX063 | 498183 | 8276112 |
| KNX064 | 498347 | 8275884 |
| KNX065 | 499096 | 8275976 |
| KNX066 | 499293 | 8275863 |
| KNX067 | 499553 | 8275702 |
| KNX068 | 499941 | 8276017 |
| KNX069 | 494623 | 8284355 |
| KNX070 | 494386 | 8284488 |
| KNX071 | 495147 | 8275209 |
| KNX072 | 495924 | 8271976 |
| KNX073 | 497457 | 8272536 |
| KNX074 | 499928 | 8275580 |
| KNX075 | 499731 | 8276074 |
| KNX076 | 499725 | 8276215 |
| KNX077 | 499575 | 8276215 |
| KNX078 | 499527 | 8275540 |
| KNX079 | 499870 | 8274079 |

| | | |
|---|---|---|
| KNX080 | 499710 | 8273636 |
| KNX081 | 499728 | 8273724 |
| KNX082 | 499644 | 8274114 |
| KNX083 | 499483 | 8274085 |
| KNX084 | 499543 | 8273867 |
| KNX085 | 499597 | 8273798 |
| KNX086 | 499080 | 8275701 |
| KNX087 | 498985 | 8275649 |
| KNX088 | 498975 | 8276373 |
| KNX089 | 498969 | 8276030 |
| KNX090 | 499357 | 8276284 |
| KNX091 | 498056 | 8271596 |
| KNX092 | 498334 | 8272281 |
| KNX093 | 497890 | 8272298 |
| KNX094 | 497943 | 8272940 |

| Site no. | Easting (m) | Northing (m) |
|---|---|---|
| KNX095 | 498013 | 8273608 |
| KNX096 | 497817 | 8273970 |
| KNX097 | 498342 | 8273168 |
| KNX098 | 499426 | 8270285 |
| KNX099 | 499718 | 8269546 |
| KNX100 | 496845 | 8282025 |
| KNX101 | 496515 | 8282056 |
| KNX102 | 495961 | 8282066 |
| KNX103 | 495327 | 8282096 |
| KNX104 | 494861 | 8282039 |
| KNX105 | 494332 | 8282091 |
| KNX106 | 494035 | 8282050 |
| KNX107 | 498581 | 8279670 |
| KNX108 | 497826 | 8279620 |
| KNX109 | 497352 | 8279639 |
| KNX110 | 497038 | 8279679 |
| KNX111 | 496612 | 8279621 |
| KNX112 | 496214 | 8279629 |
| KNX113 | 495676 | 8279680 |
| KNX114 | 495443 | 8279634 |
| KNX115 | 494939 | 8279646 |
| KNX116 | 494466 | 8279663 |
| KNX117 | 499221 | 8277078 |
| KNX118 | 499927 | 8269832 |
| KNX119 | 499791 | 8277359 |
| KNX120 | 499624 | 8277923 |
| KNX121 | 499780 | 8270237 |
| KNX122 | 499783 | 8270455 |
| KNX123 | 499602 | 8270897 |
| KNX124 | 499518 | 8270912 |
| KNX125 | 498903 | 8270947 |
| KNX126 | 497643 | 8271472 |
| KNX127 | 497422 | 8271603 |
| KNX128 | 496561 | 8271946 |
| KNX129 | 497351 | 8286682 |
| KNX130 | 496457 | 8285204 |
| KNX131 | 498421 | 8279062 |
| KNX132 | 497824 | 8278564 |
| KNX133 | 495904 | 8277086 |
| KNX134 | 499937 | 8275799 |
| KNX135 | 499977 | 8274132 |
| KNX136 | 498422 | 8272666 |
| KNX137 | 497477 | 8272559 |
| KNX138 | 497263 | 8272582 |
| KN01 | 503293 | 8267269 |
| KN02 | 502892 | 8267896 |
| KN03 | 503324 | 8268555 |
| KN04 | 503288 | 8268643 |
| KN05 | 502659 | 8268605 |
| KN06 | 503478 | 8269737 |
| KN07 | 503749 | 8270918 |
| KN08 | 503339 | 8270817 |
| KN09 | 503247 | 8273001 |
| KN10 | 503436 | 8273258 |
| KN11 | 503523 | 8275311 |
| KN12 | 503138 | 8275709 |
| KN13 | 502542 | 8276050 |

| Site no. | Easting (m) | Northing (m) |
|---|---|---|
| KN14 | 5022718 | 8273673 |
| KN15 | 501848 | 8274705 |
| KN16 | 501727 | 8273784 |
| KN17 | 501505 | 8273518 |
| KN18 | 500494 | 8274427 |
| KN19 | 500175 | 8274718 |
| KN20 | 500005 | 8275620 |
| KN21 | 499918 | 8276208 |
| KN22 | 499892 | 8276758 |
| KN23 | 500766 | 8276208 |
| KN24 | 501410 | 8276215 |
| KN25 | 502948 | 8271885 |
| KN26 | 502127 | 8272248 |
| KN27 | 501363 | 9272546 |
| KN28 | 500628 | 8271672 |
| KN29 | 500036 | 8270206 |
| KN30 | 499925 | 8268811 |

# Appendix 2. Plant species and vegetation communities

| **Community** | | **Tall tussock grass savanna** | **Tall tussock grass shrub or tree savanna** | **Open woodland** | **High grass savanna** |
|---|---|---|---|---|---|
| **Associated soil/landform** | | **Cracking clay plain** | **Cracking clay plain** | **Levees, colluvial slopes** | **Between cracking clay plain and colluvial slopes** |
| **Trees and shrubs** | **Common name** | | | | |
| *Acacia dunnii* | Elephant ear wattle | | | - | |
| *Acacia farnesiana* | Mimosa bush | - | - | | |
| *Acacia holosericea* | Candelabra wattle | | | - | |
| *Acacia sp. H* | Acacia | - | - | | |
| *Adansonia gregorii* | Boab, baobab | | | - | |
| *Atalaya hemiglauca* | Whitewood | - | + | - | |
| *Capparis umbonata* | Wild orange | | | - | |
| *Carissa lanceolata* | Conkerberry | - | - | | |
| *Cathormium umbellatum* | | | | - | |
| *Cochlospermum fraseri* | Kapok tree | | | - | |
| *Dolichandrone filiformis* | | | | - | |
| *Eucalyptus confertiflora* | Roughleaf cabbage gum | | | - | |
| *Eucalyptus microtheca* | Flooded box | - | + | - | - |
| *Eucalyptus opaca* | | | | - | |
| *Eucalyptus papuana* | Ghost gum | | - | + | - |
| *Eucalyptus* spp. | Cabbage gum | | | - | |
| *Eucalyptus tectifera* | Grey box | | | + | |
| *Excoecaria parvifolia* | Guttapercha tree | - | + | | |
| *Hakea arborescens* | Hakea | | | - | |
| *Hibiscus* spp. | Hibiscus | | | - | |
| *Lysiphyllum cunninghamii* | Bauhinia | + | + | - | |
| *Terminalia platyptera* | Wing-seed terminalia | | - | | |
| *Terminalia volucris* | Rosewood | - | + | - | |
| **Herbs/forbs/sedges** | | | | | |
| *Cyperus cunninghamii* | Sedge | - | - | | |
| *Fimbristylis* spp. | Fimbristylis | | - | | |
| *Gossypium australe* | Native cotton | | - | | |
| *Neptunia* spp. | Neptunia | | - | | |
| *Psoralea* spp. | Psoralea | - | - | | |
| *Sesbania* spp. | Sesbania pea | - | - | - | |
| *Sida spinosum* | Sida | - | - | | |
| *Tephrosia* spp. | | - | - | | |

| **Community** | | **Tall tussock grass savanna** | **Tall tussock grass shrub or tree savanna** | **Open woodland** | **High grass savanna** |
|---|---|---|---|---|---|
| **Associated soil/landform** | | **Cracking clay plain** | **Cracking clay plain** | **Levees, colluvial slopes** | **Between cracking clay plain and colluvial slopes** |
| **Grasses** | **Common name** | | | | |
| *Aristida hygrometrica* | Northern kerosene grass | | | - | |
| *Aristida latifolia* | Feathertop wiregrass | + | + | | |
| *Astrebla squarrosa* | Bull Mitchell grass | + | + | | |
| *Brachyachne convergens* | Common native couch | - | - | | |
| *Chionachne hubbardiana* | River grass | - | - | | |
| *Chrysopogon fallax* | Ribbon grass | + | + | - | |
| *Dichanthium* spp | Bluegrass | + | + | | |
| *Digitaria bicornis* | Hairy finger grass | - | - | | |
| *Eriachne obtusa* | Northern wanderrie grass | - | - | | |
| *Eulalia aurea* | Silky browntop | - | - | | |
| *Heteropogon contortus* | Bunch or black speargrass | | | - | |
| *Iseilema vaginiflorum* | Red Flinders grass | + | + | | |
| *Ophiuros exalatus* | Canegrass | - | - | | |
| *Panicum decompositum* | Native millet | - | - | | |
| *Panicum* spp. | Panic | - | - | | |
| *Sehima nervosum* | Rat's tail grass | - | - | | |
| *Sorghum* sp. | Sorghum | | | | + |
| *Sorghum plumosum* | Plume sorghum | - | - | - | + |
| *Sporobulus australasicus* | Ray grass, katoora | | | - | |
| *Themeda triandra* | Kangaroo grass | - | - | + | |

not present
\- rarely present
\+ common

# Appendix 3.

## Soil pit descriptions: morphological, chemical and physical data

Soil pits were dug at 10 sites on the Western Australian side of the border, and chemical and physical analysis recorded for each horizon, and sometimes more frequently.

**Forms of analysis**

Most chemical analysis, except for total phosphorus, followed the methods of Rayment G.R. and Higginson, F.R. (1992). *Australian laboratory handbook of soil and water chemical methods*. Inkata Press.

**Soil acidity** (pH) was measured in both water (1:5) and calcium chloride (1:5).

**Electrical conductivity** (EC) measured in milliSiemens per metre.

**Chloride** ($Cl^-$) was measured as per cent.

**Particle size distribution** was recorded as per cent, divided into coarse sand, fine sand, silt and clay fractions.

**Organic carbon** (Org C) followed the Walkley and Black method.

**Total nitrogen** (N) per cent by the Keldhahl method.

**Total phophorus** (P) in parts per million as Keldhahl digest.

**Zinc** was extracted in diethylene triamine penta acetic acid (DPTA) according to the Lindsay and Norvell Method (Lindsay, W.L. and Norvell, W.A. (1978). Soil Soc. AM. Proc. **42**: 421-)

**Exchangeable cations**: Cation exchange capacity (CEC), calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) were measured in centimols of $H^+$.

**Calcium carbonate** was measured as soluble in dilute acid.

| | |
|---|---|
| **Profile no.** | **KNX129** |
| **Australian Soil Classification** | Epicalcareous-Endohypersodic Epipedal Brown **Vertosol** |
| **Soil family** | Cununurra clay leached brown-gypsic phase |
| **Reference** | Soil survey of the Knox Creek Plain Schoknecht, Grose, Fett and Johnston 1996 |
| **Location** | 30 km NE of Kununurra, WA AMG 497351mE, 8286682mN, zone 52L |
| **Landform** | Flat cracking clay plain - map unit 1c |
| **Parent material** | Alluvium |
| **Drainage** | Restricted by swelling clay soil - very low |
| Internal: | when wet |
| | Seasonally wet or inundated |
| External: | |
| **Surface condition:** | Weakly self-mulching, thin surface crust, prominent cracks to 5 cm wide: |
| **morphology** | Weakly gilgaied |
| **Native vegetation** | **Tall tussock grass shrub or tree savanna** |
| Trees/shrubs: | *Eucalyptus microtheca, Excoecaria parvifolia, Terminalia volucris, Atalaya hemiglauca* |
| Ground: | *Cyperus cunninghamii, Panicum decompositum, Aristida latifolia, Chrysopogon fallax* |

## Morphological description

| Horizon | Depth (cm) | Description |
|---|---|---|
| A11 | 0-7 | Dark brown (10YR 4/3) light medium clay, strong granular structure (2-5 mm), slakes completely, clear boundary. |
| A12 | 7-30 | Dark brown (10YR 4/3) medium clay, strong subangular blocky structure (20-50 mm), very firm (4D), prominent cracks, very few <2 mm calcareous concretions, slightly calcareous, slakes completely, gradual boundary. |
| B21 | 30-107 | Dark brown (10YR 4/3) heavy clay, strong subangular blocky structure (100-200 mm), very strong (6D), prominent cracks, very few <2 mm calcareous concretions, slightly calcareous, slakes completely, gradual boundary. |
| B22 | 107-183+ | Dark brown (7.5YR 4/3) medium heavy clay, moderate angular blocky structure (20-50 mm), firm (3M), prominent slickensides, common 2-6 mm gypseous crystals, non-calcareous, slakes completely. |

## Chemical and physical analysis (<2 mm fraction)

| Depth cm | pH | | EC 1:5 | $Cl^-$ % | Particle size % | | | | Org C | N total | P total | Zn | Exchangeable cations cmol(+)/ kg soil | | | | | $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | $CaCl_2$ | mS/m | | CS | FS | Silt | Clay | % | % | ppm | ppm | CEC | Ca | Mg | K | Na | % |
| 0-7 | 6.8 | 6.5 | 64 | 0.01 | 2.4 | 24.2 | 27.9 | 47.9 | 0.90 | 0.048 | 90 | 0.4 | 32 | 16.8 | 17.8 | 1.7 | 0.7 | |
| 7-30 | 7.4 | 6.9 | 33 | 0.01 | 1.7 | 20.3 | 19.0 | 58.5 | 0.25 | 0.023 | 94 | 0.2 | 33 | 15.0 | 19.1 | 1.4 | 1.4 | |
| 30-65 | 8.5 | 7.8 | 48 | 0.01 | 2.0 | 20.3 | 18.8 | 58.9 | 0.20 | 0.018 | 83 | 0.1 | 35 | 14.1 | 16.5 | 0.6 | 3.9 | <2 |
| 65-107 | 7.9 | 7.7 | 350 | 0.07 | 1.2 | 19.6 | 15.7 | 63.5 | 0.16 | 0.015 | 90 | 0.1 | 37 | 14.7 | 17.6 | 0.8 | 7.5 | |
| 107-145 | 7.8 | 7.7 | 440 | 0.07 | 1.0 | 24.8 | 14.1 | 60.1 | 0.11 | 0.012 | 100 | 0.2 | 34 | 12.6 | 18.6 | 0.9 | 7.5 | |
| 145-183 | 7.9 | 7.8 | 480 | 0.10 | 3.6 | 20.8 | 27.7 | 47.9 | 0.08 | 0.010 | 100 | 0.2 | 36 | 10.8 | 20.3 | 0.7 | 9.1 | |

| | |
|---|---|
| **Profile no.** | **KNX130** |
| **Australian Soil Classification** | Epicalcareous-Endohypersodic Epipedal Grey **Vertosol** |
| **Soil family** | Cununurra clay leached brown-gypsic phase |
| **Reference** | Soil survey of the Knox Creek Plain Schoknecht, Grose, Fett and Johnston 1996 |
| **Location** | 30 km NE of Kununurra, WA AMG 496457mE, 8285204mN, zone 52L |
| **Landform** | Flat cracking clay plain - map unit 1c |
| **Parent material** | Alluvium |
| **Drainage** Internal: | Restricted by swelling clay soil - very low when wet |
| External: | Seasonally wet or inundated |
| **Surface condition: morphology** | Weakly self-mulching, surface cracks: Gilgaied - 1-2 m spacing, 10-15 cm amplitude |
| **Native vegetation** | **Tall tussock grass shrub or tree savanna** |
| Trees/shrubs: | *Eucalyptus microtheca, Excoecaria parvifolia, Atalaya hemiglauca* |
| Ground: | *Panicum decompositum, Iseilema vaginiflorum, Astrebla squarrosa, Sesbania* spp. |

## Morphological description

| Horizon | Depth (cm) | Description |
|---|---|---|
| A11 | 0-12 | Dark brown (10YR 4/3) medium clay, strong granular structure (10-20 mm), very firm (4D), prominent cracks, clear boundary. |
| A12 | 12-25 | Dark brown (10YR 4/3) medium clay, strong subangular blocky structure (20-50 mm), strong (5D), prominent cracks, gradual boundary. |
| B21 | 25-50 | Dark brown (10YR 4/3) medium heavy clay, moderate subangular blocky structure (100-200 mm) - secondary structure strong subangular blocky (50-100 mm), very strong (6T), prominent cracks, gradual boundary. |
| B22 | 50-125 | Dark brown (10YR 4/3) medium heavy clay, moderate subangular blocky structure (50-100 mm), strong (5M), very few <2 mm calcareous nodules, clear boundary. |
| B23 | 125-180+ | Dark brown (7.5YR 4/3) medium heavy clay, moderate angular blocky structure (20-50 mm), very firm (4M), common, >5 mm, gypseous crystals, slightly calcareous. |

## Chemical and physical analysis (<2 mm fraction)

| Depth cm | pH | | EC 1:5 | $Cl^-$ | Particle size % | | | | Org C | N total | P total | Zn | Exchangeable cations cmol(+)/ kg soil | | | | | $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | $CaCl_2$ | mS/m | % | CS | FS | Si | Clay | % | % | ppm | ppm | CEC | Ca | Mg | K | Na | % |
| 0-12 | 6.9 | 6.4 | 20 | | 2.4 | 17.1 | 15.1 | 65.4 | 0.67 | 0.044 | 98 | 0.3 | 36 | 15.1 | 19.4 | 1.6 | 0.6 | |
| 12-25 | 7.8 | 6.9 | 19 | | 2.3 | 13.8 | 15.1 | 68.8 | 0.26 | 0.022 | 78 | 0.1 | 38 | 18.7 | 23.3 | 1.4 | 2.2 | |
| 25-50 | 8.2 | 7.2 | 18 | | 2.5 | 16.4 | 13.7 | 67.4 | 0.22 | 0.021 | 79 | 0.1 | 39 | 15.3 | 16.9 | 0.8 | 2.8 | <2 |
| 50-90 | 8.6 | 7.8 | 38 | 0.02 | 2.3 | 13.8 | 14.9 | 69.0 | 0.28 | 0.021 | 75 | 0.1 | 40 | 14.8 | 17.2 | 0.7 | 5.3 | <2 |
| 90-125 | 8.3 | 7.8 | 110 | 0.08 | 1.3 | 14.5 | 12.7 | 71.5 | 0.21 | 0.016 | 74 | 0.2 | 40 | 13.2 | 17.7 | 0.9 | 6.9 | <2 |
| 125-180 | 7.8 | 7.7 | 440 | 0.09 | 1.1 | 23.3 | 12.5 | 63.1 | 0.08 | 0.009 | 54 | 0.1 | 38 | 14.4 | 19.2 | 0.9 | 8.2 | |

| | |
|---|---|
| **Profile no.** | **KNX131** |
| **Australian Soil Classification** | Epicalcareous-Endohypersodic Epipedal Grey **Vertosol** |
| **Soil family** | Cununurra clay leached grey phase |
| **Reference** | Soil survey of the Knox Creek Plain<br>Schoknecht, Grose, Fett and Johnston<br>1996 |
| **Location** | 30 km NE of Kununurra, WA<br>AMG 498421mE, 8279062mN, zone 52L |
| **Landform** | Flat cracking clay plain - map unit 1g |
| **Parent material** | Alluvium |
| **Drainage** | Restricted by swelling clay soil - very low |
| Internal: | when wet<br>Seasonally wet or inundated |
| External: | |
| **Surface condition:** | Common surface cracks, thin surface crust <5 mm thick |
| **morphology** | Weakly gilgaied |
| **Native vegetation** | **Tall tussock grass savanna**. |
| Trees/shrubs: | Very scattered *Lysiphyllum cunninghamii, Terminalia volucris, Atalaya hemiglauca* |
| Ground: | *Aristida latifolia, Iseilema vaginiflorum, Chrysopogon fallax, Sesbania* sp., *Psoralea* sp. |

## Morphological description

| Horizon | Depth (cm) | Description |
|---|---|---|
| A11 | 0-8 | Dark greyish brown (2.5Y 4/2) light medium clay, strong granular structure (5-10 mm), firm (3D), prominent cracks, very few <2mm manganiferous concretions, slakes completely, clear boundary. |
| A12 | 8-25 | Dark greyish brown (2.5Y 4/2) medium clay, strong subangular blocky structure (20-50 mm), very strong (6D), prominent cracks, very few <2mm manganiferous concretions, slakes completely, gradual boundary. |
| B2 | 25-113 | Dark greyish brown (2.5Y 4/2) medium heavy clay, moderate subangular block structure (100-200 mm) - secondary structure strong subangular blocky (50-100 mm), rigid (7T), prominent cracks to 50 cm, very few <2 mm manganiferous concretions, slakes completely, gradual boundary. |
| BC | 113-156 | Brown (7.5YR 4/4), medium clay, apedal, firm (3M), very few <2mm calcareous and manganiferous concretions, slakes completely, gradual boundary. |
| C | 156-185+ | Strong brown (7.5YR 4.5/6), medium clay, weak angular blocky (20-50 mm) apedal, firm (3M), very few to few <2 mm calcareous and manganiferous |

concretions, slakes completely.

## Chemical and physical analysis (<2 mm fraction)

| Depth cm | pH | | EC 1:5 | $Cl^-$ % | Particle size % | | | | Org C | N total | P total | Zn | Exchangeable cations cmol(+)/ kg soil | | | | | $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | $CaCl_2$ | mS/m | | CS | FS | Silt | Clay | % | % | ppm | ppm | CEC | Ca | Mg | K | Na | % |
| 0-8 | 6.9 | 6.2 | 11 | | 10.4 | 37.7 | 11.6 | 40.3 | 0.76 | 0.054 | 65 | 0.2 | 26 | 14.9 | 12.9 | 0.7 | 0.2 | |
| 8-25 | 7.9 | 7.0 | 5 | | 10.6 | 37.7 | 11.3 | 42.6 | 0.29 | 0.023 | 42 | 0.1 | 26 | 17.2 | 12.3 | 0.3 | 0.4 | |
| 25-70 | 8.9 | 7.7 | 9 | | 10.9 | 35.6 | 10.7 | 42.8 | 0.20 | 0.019 | 39 | 0.1 | 27 | 15.2 | 11.9 | 0.2 | 1.6 | <2 |
| 70-113 | 9.1 | 8.1 | 32 | 0.02 | 11.2 | 33.7 | 11.4 | 43.7 | 0.24 | 0.019 | 39 | <0.1 | 27 | 10.5 | 12.5 | 0.2 | 4.1 | 2 |
| 113-156 | 8.5 | 8.0 | 130 | 0.11 | 10.6 | 30.5 | 10.9 | 48.0 | 0.11 | 0.012 | 40 | <0.1 | 28 | 10.6 | 12.9 | 0.2 | 5.5 | <2 |
| 156-185 | 8.8 | 8.0 | 58 | 0.40 | 14.1 | 31.5 | 8.4 | 46.0 | 0.06 | 0.010 | 49 | <0.1 | 24 | 8.4 | 10.3 | 0.2 | 4.8 | <2 |

| | |
|---|---|
| **Profile no.** | **KNX132** |
| **Australian Soil Classification** | Haplic Eutrophic Red **Chromosol** |
| **Soil family** | Bonaparte |
| **Reference** | Soil survey of the Knox Creek Plain<br>Schoknecht, Grose, Fett and Johnston<br>1996 |
| **Location** | 30 km NE of Kununurra, WA<br>AMG 497824mE, 8278564mN, zone 52L |
| **Landform** | Flat cracking clay plain - map unit 7f |
| **Parent material** | Alluvium |
| **Drainage** | Moderate in B2, rapid in deep subsoil |
| Internal: | Seasonally wet or inundated |
| External: | |
| **Surface condition:** | Soft: |
| **morphology** | smooth |
| **Native vegetation** | **Open woodland**. |
| Trees/shrubs: | *Eucalyptus papuana, Hakea arborescens, Lysiphyllum cunninghamii, Terminalia volucris, Atalaya hemiglauca* |
| Ground: | *Themeda triandra, Heteropogon contortus, Sporobolus australisicus* |

## Morphological description

| Horizon | Depth (cm) | Description |
|---|---|---|
| A1 | 0-15 | Dark brown (7.5Y 4/2), light sandy clay loam, weak platy structure (20-50 mm), porous, weak consistence (2D) clear boundary. |
| B2 | 15-75 | Yellowish red (5YR 4/6), medium clay, strong prismatic structure, (50-100 mm), very firm (4D), very few <2mm manganiferous concretions, clay cutans, clear boundary. |
| BC | 75-115 | Yellowish red (5YR 4/6), light sandy clay loam, apedal, firm (3D), massive, gradual boundary. |
| C1 | 115-170 | Yellowish red (5YR 4/6), clayey sand, apedal, massive, firm (3T), diffuse boundary. |
| C2 | 170-200 | Yellowish red (5YR 5/8), weak clayey sand, apedal, massive, very weak (1D), evidence of organic stained layers, clear boundary. |
| C3 | 200-220+ | Strong brown (7.5YR 6/8), weak clayey sand, apedal, loose consistence (0T), massive. |

## Chemical and physical analysis (<2 mm fraction)

| Depth cm | pH | | EC 1:5 | $Cl^-$ % | Particle size % | | | | Org C | N total | P total | Zn | Exchangeable cations cmol(+)/ kg soil | | | | | $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | $CaCl_2$ | mS/m | | CS | FS | Silt | Clay | % | % | ppm | ppm | CEC | Ca | Mg | K | Na | % |
| 0-15 | 6.7 | 5.8 | 3 | | 52.7 | 32.6 | 4.0 | 10.7 | 0.46 | 0.033 | 82 | 0.1 | 16 | 8.0 | 6.7 | 0.7 | 0.1 | |
| 15-45 | 6.5 | 5.8 | 4 | | 29.8 | 18.7 | 5.8 | 45.7 | 0.38 | 0.037 | 97 | 0.1 | 17 | 9.1 | 7.1 | 0.7 | 0.1 | |
| 45-75 | 6.7 | 5.8 | 2 | | 27.7 | 23.4 | 4.7 | 44.2 | 0.24 | 0.030 | 100 | <0.1 | 16 | 7.9 | 6.6 | 0.7 | 0.1 | |
| 75-115 | 6.8 | 6.0 | 2 | | 48.1 | 25.7 | 2.8 | 23.4 | 0.11 | 0.016 | 90 | 0.1 | 8 | 4.2 | 3.6 | 0.4 | 0.06 | |
| 115-170 | 6.9 | 6.2 | 2 | | 63.0 | 20.9 | 1.8 | 14.3 | 0.04 | 0.008 | 56 | <0.1 | 6 | 3.0 | 2.6 | 0.3 | 0.05 | |
| 170-200 | 7.2 | 6.6 | 2 | | 87.8 | 6.3 | 1.2 | 4.7 | 0.01 | 0.005 | 32 | <0.1 | 2 | 1.4 | 1.2 | 0.1 | 0.04 | |

| | |
|---|---|
| **Profile no.** | **KNX133** |
| **Australian Soil Classification** | Epicalcareous-Endohypersodic Epipedal Brown **Vertosol** |
| **Soil family** | Cununurra clay leached grey-gypsic phase |
| **Reference** | Soil survey of the Knox Creek Plain Schoknecht, Grose, Fett and Johnston 1996 |
| **Location** | 30 km NE of Kununurra, WA AMG 495904mE, 8277086mN, zone 52L |
| **Landform** | Flat cracking clay plain - map unit 1d |
| **Parent material** | Alluvium |
| **Drainage** | Restricted by swelling clay soil - very low |
| Internal: | when wet |
| | Seasonally wet or inundated |
| External: | |
| **Surface condition:** | Weakly self-mulching, occasional surface cracks |
| **morphology** | Gilgaied - 1-2 m spacing, 10-15 cm amplitude |
| **Native vegetation** | **Tall tussock grass shrub or tree savanna** |
| Trees/shrubs: | *Excoecaria parvifolia, Terminalia volucris, Eucalyptus microtheca* |
| Ground: | *Astrebla squarrosa, Chrysopogon fallax, Cyperus cunninghamii* |

## Morphological description

| Horizon | Depth (cm) | Description |
|---|---|---|
| A11 | 0-5 | Dark brown (10YR 4/3) light medium clay, moderate subangular blocky structure (10-20 mm), strong (5D), slakes completely, clear boundary. |
| A12 | 5-45 | Dark brown (10YR 4/3) medium clay, strong subangular blocky structure (50-100 mm), strong (5D), slakes completely, gradual boundary. |
| B21 | 45-79 | Dark brown (10YR 4/3) medium heavy clay, strong angular blocky structure (20-50 mm), very strong (6T), very few <2 mm manganiferous nodules, very few <2 mm, calcareous concretions, slakes completely, gradual boundary. |
| B22 | 79-148 | Dark brown (10YR 4/3) medium heavy clay, strong subangular blocky structure (50-100 mm), very strong (6T), slickensides, very few <2 mm manganiferous nodules, very few <2 mm, calcareous concretions, slightly calcareous, slakes partially, gradual boundary. |
| B23 | 148-200+ | Dark brown (7.5YR 4/3) medium clay, strong angular |

blocky structure (50-100 mm), very firm (4M), slickensides, very few <2 mm, calcareous concretions and gypsum crystals, slightly calcareous, slakes partially.

## Chemical and physical analysis (<2 mm fraction)

| Depth cm | pH | | EC 1:5 | $Cl^-$ % | Particle size % | | | | Org C | N total | P total | Zn | Exchangeable cations cmol(+)/kg soil | | | | | $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | $CaCl_2$ | mS/m | | CS | FS | Silt | Clay | % | % | ppm | ppm | CEC | Ca | Mg | K | Na | % |
| 0-5 | 6.8 | 6.5 | 56 | | 3.8 | 18.7 | 19.7 | 57.8 | 0.73 | 0.042 | 74 | 0.3 | 33 | 22.3 | 13.8 | 1.4 | 0.6 | |
| 5-45 | 7.4 | 7.1 | 79 | | 2.9 | 15.3 | 19.4 | 62.4 | 0.26 | 0.023 | 59 | 0.1 | 34 | 25.9 | 14.8 | 1.3 | 1.0 | <2 |
| 45-79 | 8.0 | 7.6 | 74 | 0.01 | 3.0 | 17.0 | 18.3 | 61.7 | 0.28 | 0.022 | 62 | 0.1 | 36 | 21.0 | 12.5 | 0.7 | 2.8 | <2 |
| 79-148 | 8.6 | 7.9 | 62 | 0.03 | 2.8 | 14.5 | 19.6 | 63.1 | 0.22 | 0.019 | 64 | 0.1 | 37 | 18.0 | 13.6 | 0.7 | 4.6 | |
| 148-200 | 7.8 | 7.7 | 380 | 0.04 | 2.9 | 60.5 | 6.4 | 30.2 | 0.08 | 0.010 | 55 | 0.1 | 36 | 18.0 | 15.7 | 0.7 | 5.5 | |

| | |
|---|---|
| **Profile no.** | **KNX134** |
| **Australian Soil Classification** | Endocalcareous-Endohypersodic Epipedal Grey **Vertosol** |
| **Soil family** | Cununurra clay leached grey stony phase |
| **Reference** | Soil survey of the Knox Creek Plain<br>Schoknecht, Grose, Fett and Johnston<br>1996 |
| **Location** | 30 km NE of Kununurra, WA<br>AMG 499937mE, 8275799mN, zone 52L |
| **Landform** | Flat cracking clay plain - map unit 1ds |
| **Parent material** | Alluvium |
| **Drainage** | Restricted by swelling clay soil - very low |
| Internal: | when wet |
| | Seasonally wet or inundated |
| External: | |
| **Surface condition:** | Up to 30% stones (20-50 cm) strewn over surface, weakly self-mulching, occasional surface cracks: |
| **morphology** | Weak to moderately gilgaied, 1-3 m spacing, 10-15 cm amplitude |
| **Native vegetation** | **Tall tussock grass shrub or tree savanna** |
| Trees/shrubs: | (Scattered): *Acacia* sp. *H., Excoecaria parvifolia, Atalaya hemiglauca, Lysiphyllum cunninghamii* |
| Ground: | *Chrysopogon fallax, Panicum* sp., *Cyperus cunninghamii* |

## Morphological description

| Horizon | Depth (cm) | Description |
|---|---|---|
| A11 | 0-10 | Dark greyish brown (10YR 4/2) medium clay, strong subangular blocky structure (20-50 mm), very firm (4D), prominent cracks, few fine faint rootline mottles (10YR 5/6); clear boundary. |
| A12 | 10-47 | Dark greyish brown (10YR 4/2) medium heavy clay, strong prismatic structure (100-200 mm), very strong (6D), slickensides, prominent cracks, gradual boundary. |
| B21 | 47-77 | Dark greyish brown (10YR 4/2) medium heavy clay, moderate angular blocky structure (50-100 mm), very strong (6T), slickensides, very few <2 mm calcareous concretions, gradual boundary. |
| B22 | 77-115 | Dark brown (10YR 4/3) medium clay, moderate angular blocky structure (20-50 mm), strong (5M), slickensides, very few <2 mm, calcareous concretions, clear boundary. |
| B23 | 115-200+ | Dark brown (10YR 4/3) medium clay, moderate angular blocky structure (50-100 mm), very firm (4M), prominent slickensides, very few <2 mm, calcareous concretions, common <2 mm gypsum crystals. |

## Chemical and physical analysis (<2 mm fraction)

| Depth cm | pH | | EC 1:5 | $Cl^-$ | Particle size % | | | | Org C | N total | P total | Zn | Exchangeable cations cmol(+)/ kg soil | | | | | $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | $CaCl_2$ | mS/m | % | CS | FS | Silt | Clay | % | % | ppm | ppm | CEC | Ca | Mg | K | Na | % |
| 0-10 | 6.7 | 6.3 | 47 | | 4.9 | 17.7 | 16.1 | 61.3 | 0.56 | 0.035 | 53 | 0.2 | 37 | 14.6 | 24.2 | 1.5 | 1.1 | |
| 10-47 | 7.7 | 7.0 | 37 | 0.01 | 3.2 | 14.2 | 15.6 | 67.0 | 0.32 | 0.019 | 48 | 0.1 | 40 | 14.7 | 25.8 | 1.2 | 3.6 | |
| 47-77 | 7.8 | 7.4 | 130 | 0.07 | 3.3 | 112.7 | 15.0 | 69.0 | 0.30 | 0.019 | 49 | 0.1 | 43 | 14.7 | 21.9 | 0.6 | 6.3 | |
| 77-115 | 7.8 | 7.6 | 370 | 0.08 | 2.5 | 18.0 | 13.4 | 66.1 | 0.18 | 0.013 | 41 | 0.1 | 44 | 12.3 | 24.8 | 0.7 | 7.8 | |
| 115-155 | 7.8 | 7.7 | 440 | 0.08 | 1.8 | 32.4 | 10.7 | 55.1 | 0.08 | 0.008 | 35 | 0.1 | 37 | 11.6 | 21.8 | 0.6 | 6.9 | |
| 155-200 | 8.0 | 7.8 | 440 | 0.09 | 2.7 | 30.6 | 12.3 | 54.4 | 0.08 | 0.007 | 40 | 0.1 | 35 | 12.3 | 21.2 | 0.5 | 6.7 | 3 |

| | |
|---|---|
| **Profile no.** | **KNX135** |
| **Australian Soil Classification** | Endocalcareous Epipedal Grey **Vertosol** |
| **Soil family** | Cununurra clay leached grey-gypsic phase |
| **Reference** | Soil survey of the Knox Creek Plain<br>Schoknecht, Grose, Fett and Johnston 1996 |
| **Location** | 30 km NE of Kununurra, WA<br>AMG 499977mE, 8274132mN, zone 52L |
| **Landform** | Flat cracking clay plain - map unit 1d |
| **Parent material** | Alluvium |
| **Drainage**<br>Internal:<br>External: | Restricted by swelling clay soil - very low when wet<br>Seasonally wet or inundated |
| **Surface condition:**<br>**morphology** | Thin surface crust <5 mm, prominent surface cracks:<br>Weakly gilgaied - 1-3 m spacing, up to 15 cm amplitude |
| **Native vegetation**<br>Trees/shrubs:<br>Ground: | **Tall tussock grass shrub or tree savanna**<br>Scattered *Eucalyptus microtheca*, *Excoecaria parvifolia, Acacia* sp. *H*<br>*Chrysopogon fallax, Aristida latifolia* |

## Morphological description

| Horizon | Depth (cm) | Description |
|---|---|---|
| A11 | 0-6 | Dark greyish brown (10YR 4/2) medium clay, strong subangular blocky structure (10-20 mm), very strong, (6D), prominent cracks, slakes completely, clear boundary. |
| A12 | 6-50 | Dark greyish brown (2.5Y 4/2) medium heavy clay, strong prismatic structure (100-200 mm), rigid (7D), prominent cracks, very few <2mm manganiferous nodules, gradual boundary. |
| B21 | 50-141 | Dark greyish brown (10YR 4/2) medium heavy clay, moderate subangular blocky structure (50-100 mm), strong (5T), slickensides, very few <2 mm calcareous concretions and manganiferous nodules, slightly calcareous, slakes completely, gradual boundary. |
| B22 | 141-200+ | Dark brown (10YR 4/2.5) medium heavy clay, moderate subangular blocky structure (50-100 mm), strong (5T), slickensides, very few <2 mm calcareous concretions, few <2 mm gypsum |

crystals, slightly calcareous, slakes completely.

## Chemical and physical analysis (<2 mm fraction)

| Depth cm | pH | | EC 1:5 | $Cl^-$ % | Particle size % | | | | Org C | N total | P total | Zn | Exchangeable cations cmol(+)/kg soil | | | | | $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | $CaCl_2$ | mS/m | | CS | FS | Silt | Clay | % | % | ppm | ppm | CEC | Ca | Mg | K | Na | % |
| 0-6 | 7.1 | 6.6 | 31 | | 4.0 | 20.4 | 15.9 | 59.7 | 0.44 | 0.026 | 61 | 0.2 | 34 | 20.2 | 14.9 | 1.4 | 0.5 | |
| 6-50 | 7.8 | 7.1 | 15 | | 4.1 | 20.9 | 15.2 | 60.1 | 0.26 | 0.019 | 49 | 0.1 | 36 | 21.0 | 15.8 | 1.2 | 0.6 | |
| 50-95 | 8.6 | 7.6 | 13 | | 3.4 | 18.5 | 15.9 | 62.2 | 0.29 | 0.019 | 49 | 0.2 | 35 | 18.3 | 13.7 | 0.6 | 1.8 | <2 |
| 95-141 | 8.5 | 7.8 | 42 | 0.01 | 11.1 | 32.7 | 11.2 | 45.0 | 0.25 | 0.017 | 54 | 0.1 | 37 | 18.3 | 15.7 | 0.6 | 3.0 | <2 |
| 141-200 | 7.8 | 7.7 | 320 | 0.01 | 4.4 | 38.3 | 12.0 | 45.3 | 0.013 | 0.009 | 41 | 0.1 | 33 | 18.9 | 15.3 | 0.5 | 3.1 | |

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|---|---|
| **Profile no.** | **KNX136** |
| **Australian Soil Classification** | Endocalcareous-endohypersodic Epipedal Grey **Vertosol** |
| **Soil family** | Cununurra clay leached grey-gypsic phase |
| **Reference** | Soil survey of the Knox Creek Plain Schoknecht, Grose, Fett and Johnston 1996 |
| **Location** | 30 km NE of Kununurra, WA AMG 498422mE, 8272666mN, zone 52L |
| **Landform** | Flat cracking clay plain - map unit 1g |
| **Parent material** | Alluvium |
| **Drainage** | Restricted by swelling clay soil - very low |
| Internal: | when wet |
| | Seasonally wet or inundated |
| External: | |
| **Surface condition:** | Thin crust up to 5 mm, weakly self-mulching |
| **morphology:** | Gilgaied - 1-2 m spacing, 10-20 cm amplitude |
| **Native vegetation** | **Tall tussock grass savanna** |
| Trees/shrubs: | Very scattered *Acacia* sp. *H, Atalaya hemiglauca* |
| Ground: | *Chrysopogon fallax, Aristida latifolia, Iseilema vaginiflorum* |

## Morphological description

| Horizon | Depth (cm) | Description |
|---|---|---|
| A1 | 0-7 | Dark greyish brown (10YR 4/2) light medium clay, strong subangular blocky structure (5-10 mm), firm (3D), common fine prominent reddish yellow (7.5YR 6/8) mottles, clear boundary. |
| B1 | 7-56 | Dark greyish brown (2.5Y 4/2) medium clay, strong prismatic structure (100-200 mm), strong (5T), few slickensides, gradual boundary. |
| B21 | 56-134 | Dark greyish brown (2.5Y 4/2) medium heavy clay, moderate angular blocky structure (20-50 mm), strong (5M), slickensides, very few <2 mm calcareous and manganiferous concretions, slightly calcareous, gradual boundary. |
| B22 | 134-200+ | Dark yellowish brown (10YR 4/4) medium clay, moderate subangular blocky structure (20-50 mm), strong (5M), very few <2 mm calcareous and manganiferous concretions, slakes completely. |

## Chemical and physical analysis (<2 mm fraction)

| Depth cm | pH | | EC 1:5 | $Cl^-$ % | Particle size % | | | | Org C | N total | P total | Zn | Exchangeable cations cmol(+)/kg soil | | | | | $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | $CaCl_2$ | mS/m | | CS | FS | Silt | Clay | % | % | ppm | ppm | CEC | Ca | Mg | K | Na | % |
| 0-7 | 6.9 | 6.3 | 10 | | 10.4 | 28.9 | 15.9 | 44.8 | 0.63 | 0.038 | 64 | 0.2 | 24 | 14.2 | 10.3 | 0.8 | 0.2 | |
| 7-56 | 8.1 | 7.4 | 16 | | 11.3 | 28.3 | 11.6 | 49.8 | 0.26 | 0.018 | 42 | 0.1 | 28 | 17.1 | 10.7 | 0.4 | 0.9 | |
| 56-96 | 8.9 | 8.0 | 22 | | 8.3 | 27.1 | 12.7 | 51.9 | 0.28 | 0.018 | 46 | 0.1 | 27 | 13.4 | 10.7 | 0.4 | 2.9 | |
| 96-134 | 8.8 | 8.0 | 61 | 0.03 | 10.4 | 25.2 | 12.3 | 52.1 | 0.21 | 0.015 | 45 | 0.1 | 30 | 13.0 | 12.6 | 0.4 | 4.5 | |
| 134-200 | 8.6 | 8.1 | 96 | 0.03 | 11.4 | 26.7 | 13.0 | 48.9 | 0.09 | 0.009 | 40 | <0.1 | 28 | 12.8 | 13.2 | 0.3 | 4.5 | |

**Profile no.** **KNX137**

**Australian Soil Classification** Sodic Eutrophic Red **Dermosol**

**Soil family** Bonaparte/Weaber

**Reference** Soil survey of the Knox Creek Plain
Schoknecht, Grose, Fett and Johnston
1996

**Location** 30 km NE of Kununurra, WA
AMG 497477mE, 8272559mN, zone 52L

**Landform** Flat remnant levee clay plain - map unit 7f

**Parent material** Alluvium

**Drainage** Moderate
Internal: Seasonally wet or inundated
External:

**Surface condition:** Firm
**morphology** Smooth

**Native vegetation** **Open woodland**
Trees/shrubs: *Eucalyptus microtheca* (dominant*), Atalaya hemiglauca, Lysiphyllum cunninghamii*
Ground: *Themeda triandra, Aristida latifolia, Eriachne obtusa, Brachyachne convergens, Sporobulus australasicus*

## Morphological description

| Horizon | Depth (cm) | Description |
|---|---|---|
| A11 | 0-3 | Dark reddish brown (2.5YR 3/3) loamy sand, apedal and massive, very weak consistence (1D), sharp boundary. |
| B1 | 3-13 | Reddish brown (2.5YR 4/4) fine sandy clay loam, moderate subangular blocky (20-50 mm), firm consistence (3D), clear boundary. |
| B21 | 13-54 | Reddish brown (5YR 4/4) light clay, strong subangular blocky (20-50 mm), very firm (4D), few <2 mm manganiferous nodules, gradual boundary. |
| B22 | 54-175+ | Yellowish brown (10YR 5/4) sandy light clay, weak subangular blocky structure (50-100 mm), strong (5D), moderate fine distinct strong brown (7.5YR 5/6) mottles, manganese staining, few <2 mm manganiferous nodules. |

## Chemical and physical analysis (<2 mm fraction)

| Depth | pH | EC | $Cl^-$ | Particle size | Org | N | P | Zn | Exchangeable cations | $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|

| cm | | | 1:5 | % | % | | | | C | total | total | | cmol(+)/ kg soil | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | $CaCl_2$ | mS/m | | CS | FS | Silt | Clay | % | % | ppm | ppm | CEC | Ca | Mg | K | Na | % |
| 0-3 | 6.8 | 6.2 | 7 | | 20.2 | 65.2 | 4.8 | 9.8 | 0.75 | 0.056 | 100 | 0.4 | 5 | 3.2 | 2.0 | 0.4 | 4.5 | |
| 3-13 | 6.8 | 6.0 | 4 | | 15.6 | 53.3 | 6.2 | 24.9 | 0.56 | 0.041 | 110 | 0.1 | 10 | 4.8 | 3.7 | 0.6 | 0.1 | |
| 13-54 | 6.8 | 6.1 | 6 | | 6.0 | 50.2 | 5.4 | 38.4 | 0.40 | 0.032 | 96 | <0.1 | 14 | 7.2 | 6.1 | 0.5 | 0.2 | |
| 54-115 | 7.2 | 6.3 | 5 | | 12.3 | 52.5 | 5.7 | 29.5 | 0.18 | 0.013 | 61 | <0.1 | 12 | 5.6 | 5.7 | 0.3 | 0.4 | |
| 115-175 | 7.3 | 7.1 | 100 | 0.01 | 8.4 | 55.5 | 5.9 | 30.2 | 0.10 | 0.013 | 60 | 0.1 | 13 | 10.2 | 7.2 | 1.0 | 1.0 | |

| | |
|---|---|
| **Profile no.** | **KNX138** |
| **Australian Soil Classification** | Endocalcareous-Endohypersodic Epipedal Grey **Vertosol** |
| **Soil family** | Bonaparte/Weaber |
| **Reference** | Soil survey of the Knox Creek Plain<br>Schoknecht, Grose, Fett and Johnston<br>1996 |
| **Location** | 30 km NE of Kununurra, WA<br>AMG 497263mE, 8272582mN, zone 52L |
| **Landform** | Flat cracking levee clay plain - map unit 1d |
| **Parent material** | Alluvium |
| **Drainage** | Restricted by swelling clay soil - very low |
| Internal: | when wet |
| | Seasonally wet or inundated |
| External: | |
| **Surface condition:** | Surface crust <5 mm, surface cracks |
| **morphology** | Gilgaied 1 m spacing, 5-10 cm amplitude |
| **Native vegetation** | **Tall tussock grass shrub or tree savanna** |
| Trees/shrubs: | *Lysiphyllum cunninghamii, Terminalia volucris, Atalaya hemiglauca, Excoecaria parvifolia* |
| Ground: | *Aristida latifolia, Chrysopogon fallax, Iseilema vaginiflorum* |

## Morphological description

| Horizon | Depth (cm) | Description |
|---|---|---|
| A11 | 0-6 | Dark greyish brown (10YR 4/2) medium clay, moderate granular structure (5-10 mm), firm (3D), prominent cracks, clear boundary. |
| A12 | 6-25 | Dark greyish brown (2.5Y 4/2) medium heavy clay, strong subangular blocky structure (20-50 mm), very firm (4D), prominent cracks, very few <2 mm manganiferous concretions, gradual boundary. |
| B21 | 25-102 | Dark greyish brown (2.5Y 4/2) medium heavy clay, weak prismatic structure (50-100 mm) breaking to strong angular blocky structure (20-50 mm), strong (5T), prominent cracks to 60 cm, slickensides, very few <2 mm calcareous and manganiferous concretions, clear boundary. |
| B22 | 102-180+ | Yellowish brown (7.5YR 4/3) medium clay, moderate angular blocky structure (50-100 mm), strong (5M), slickensides, very few <2 mm manganiferous concretions and few 2-6 mm gypsum crystals. |

## Chemical and physical analysis (<2 mm fraction)

| Depth cm | pH | | EC 1:5 | $Cl^-$ % | Particle size % | | | | Org C | N total | P total | Zn | Exchangeable cations cmol(+)/kg soil | | | | | $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | $CaCl_2$ | mS/m | | CS | FS | Silt | Clay | % | % | ppm | ppm | CEC | Ca | Mg | K | Na | % |
| 0-6 | 6.6 | 6.1 | 23 | | 13.4 | 26.6 | 13.8 | 46.2 | 0.63 | 0.039 | 60 | 0.3 | 26 | 12.1 | 14.0 | 1.2 | 0.3 | |
| 6-25 | 6.8 | 6.4 | 31 | | 11.5 | 24.6 | 13.4 | 50.5 | 0.33 | 0.021 | 40 | 0.1 | 28 | 15.1 | 14.3 | 0.9 | 0.6 | |
| 25-72 | 7.6 | 7.2 | 87 | 0.01 | 12.2 | 25.2 | 13.4 | 50,.5 | 0.30 | 0.018 | 46 | 0.1 | 28 | 18.6 | 14.3 | 1.0 | 1.8 | |
| 72-102 | 8.2 | 7.9 | 150 | 0.02 | 12.8 | 22.8 | 14.1 | 50.3 | 0.30 | 0.019 | 40 | <0.1 | 29 | 15.6 | 13.0 | 0.4 | 3.9 | 2 |
| 102-180 | 7.9 | 7.8 | 430 | 0.07 | 8.2 | 31.8 | 12.5 | 47.5 | 0.13 | 0.010 | 36 | <0.1 | 29 | 11.2 | 17.1 | 0.5 | 7.0 | |

# Appendix 4. 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. | • Ivanhoe West Bank<br>• Weaber Plain<br>• 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. *Lysiphyllum cunninghamii* woodland. | • 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. | • Ivanhoe Plain |
| 1c | Brownish cracking clays (Cununurra leached and brown phases); northern parts of the Knox Creek Plain. | • Knox Creek Plain |
| 1d | Greyish cracking clays with relatively coarsely structured almost neutral pH topsoils (Cununurra leached phase). | • Knox Creek Plain |
| 1ds | As for 1d, but with a stony surface. | • Knox Creek Plain |
| 1e | Channels/depressions in cracking clay plain; grey and brown cracking clays. | • Knox Creek Plain |
| 1f | Cracking clay plain with complex pattern of minor remnant levees. | • Knox Creek Plain |
| 1g | Grey cracking clays with self-mulching surface, carbonate and manganese nodules and gypsum crystals at depth. | • Weaber Plain<br>• Knox Creek Plain |
| 2a | Red-brown Earths* (Bonaparte normal phase); occurs as 'islands' in broad cracking clay plains. Low eucalypt woodlands. | • 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. | • Weaber Plain<br>• Lower Weaber - Keep Plains |

| | | |
|---|---|---|
| 2c | Red earths with sandy topsoils (Weaber normal phase); occurs as 'islands' in broad cracking clay plains. Eucalypt woodland. | • Ivanhoe Plain<br>• Weaber Plain<br>• Lower Weaber - Keep Plains |

| Unit | Description | Survey |
|---|---|---|
| 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. | • Weaber Plain<br>• Lower Weaber - Keep Plains |
| 2e | Red earths with heavy textured topsoils (Weaber heavier phase); occur as 'islands' in broad cracking clay plains. Eucalypt woodland. | • Ivanhoe Plain |
| 2f | Almost flat red soil plain; red soils, usually loams or clay loams over clay (duplex); hardsetting surface. | • Ivanhoe West Bank |
| 2g | Dissected red soil and levee plain; some areas of active erosion; variable soils, often with red clayey subsoil, exposed. | • Ivanhoe West Bank |
| 2h | Active erosion, inhospitable subsoils high in carbonates, exposed. | • 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 *Melaleuca minutifolia* woodland. | • 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. | • 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. *Grevillea striata* open woodland. | • 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. *Eucalyptus microtheca* open woodland. | • Lower Weaber - Keep Plains |
| 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. *Eucalyptus papuana* open woodland. | • Lower Weaber - Keep Plains |

| Unit | Description | Survey |
|---|---|---|
| 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. | • Weaber Plain<br>• 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. | • 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. | • Ivanhoe Plain<br>• Weaber Plain<br>• 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. *Eucalyptus papuana* open woodland. | • Weaber Plain<br>• 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. | • Weaber Plain<br>• Lower Weaber - Keep Plains |
| 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 *Eucalyptus microtheca/Excoecaria parvifolia* woodland. | • Ivanhoe Plain<br>• Weaber Plain<br>• Lower Weaber - Keep Plains |
| 5at | As for 5a but vegetation dominated by species other than *Eucalyptus microtheca* and *Excoecaria parviflora (mostly Terminalia* spp. | • Weaber Plain |

| Unit | Description | Survey |
|---|---|---|
| 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 *Eucalyptus microtheca/Excoecaria parvifolia* woodland. | • Ivanhoe West Bank<br>• Ivanhoe Plain<br>• Weaber Plain<br>• Lower Weaber - Keep Plains<br>• Knox Creek Plain |
| 5bt | As for 5b but vegetation dominated by species other than *Eucalyptus microtheca* and *Excoecaria parvifolia (Atalaya hemiglauca* and *Lysiphyllum cunninghamii).* | • 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<br>• Weaber Plain<br>• 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<br>• 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<br>• Lower Weaber - Keep Plains |
| 6a | Greater than 50% silicified sandstone in clay matrix. | • Weaber Plain |
| 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<br>• Weaber Plain<br>• Lower Weaber - Keep Plains<br>• Knox Creek Plain |

| Unit | Description | Survey |
|---|---|---|
| 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 *Lysiphyllum cunninghamii* woodland. | • Ivanhoe Plain<br>• Weaber Plain<br>• Lower Weaber - Keep Plains<br>• 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. *Eucalyptus microtheca* dominated woodland, some *Excoecaria parvifolia.* | • Weaber Plain<br>• Knox Creek Plain<br>• Ivanhoe Plan |
| 8b | Complex zone between unit 8a and Sandy Land System; soils very variable, mostly duplex. Variable woodland with *Eucalyptus polycarpa* and *E. microtheca.* | • Weaber Plain |
| 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 *Lysiphyllum cunninghamii, Carissa lanceolata* 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 *Lysiphyllum cunninghamii* and *Carissa lanceolata.* | • 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 *Lysiphyllum cunninghamii* and *Carissa lanceolata*. | • Ivanhoe Plain<br>• Weaber Plain |

| Unit | Description | Survey |
|---|---|---|
| 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<br>• 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<br>• 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 5. Definition of suitability classes

| Class | Description |
|---|---|
| Suitable | High to very high suitability for the proposed land use. There may be minor soil or landscape limitations which affect productive land use or land degradation, but these can be overcome by careful planning and management. |
| Marginally suitable | Fair suitability for the proposed land use. Moderate soil or landscape limitations will affect productive land use or land degradation. Limitations may be overcome by careful planning or management, but the cost of the additional measures required will influence the economics of the proposed land use. |
| Unsuitable | Low to very low suitability for the proposed land use. High to severe soil or landscape limitations which will affect productive land use or land degradation. Limitations may be overcome by specialised planning and management, although these measures are usually prohibitive in terms of either development costs or the associated risks of land degradation. |

# Appendix 6. EC and pH data for representative soils

| Site KNX | Map unit | Soil type | Depth upper (cm) | Depth lower (cm) | pH 1:5 water | EC 1:5 mS/m | Cl (%) | Sulphates present **** |
|---|---|---|---|---|---|---|---|---|
| 05 | 1c | Cununurra clay | 0 | 10 | 7.2 | 10 | 0 | |
| | | leached | 25 | 35 | 7.2 | 4 | 0 | |
| | | brown phase | 110 | 120 | 6.9 | 32 | 0 | |
| 13 | 1c | Cununurra clay | 0 | 10 | 7.4 | 4 | 0 | |
| | | leached | 50 | 60 | 8.3 | 45 | 0.05 | |
| | | brown-gypsic | 110 | 120 | 7.6 | 389 | 0.12 | **** |
| | | phase | 170 | 180 | 7.5 | 432 | 0.14 | **** |
| 16 | 1c | Cununurra clay | 0 | 5 | 6.6 | 6 | 0 | |
| | | leached | 10 | 15 | 7.0 | 5 | 0 | |
| | | brown-gypsic | 60 | 65 | 9.0 | 19 | 0 | |
| | | phase | 110 | 120 | 7.7 | 391 | 0.09 | **** |
| 17 | 1c | Cununurra clay | 0 | 5 | 7.1 | 8 | 0 | |
| | | leached | 15 | 20 | 7.3 | 5 | 0 | |
| | | brown-gypsic | 90 | 95 | 8.2 | 130 | 0.11 | |
| | | phase | 220 | 250 | 7.7 | 403 | 0.1 | **** |
| 20 | 1d | Cununurra clay | 0 | 5 | 8.2 | 9 | 0 | |
| | | leached grey | 50 | 55 | 9.0 | 17 | 0 | |
| | | phase | 115 | 120 | 7.7 | 375 | 0.03 | |
| | | | 150 | 155 | 7.5 | 359 | 0.03 | **** |
| 22 | 1f | Cununurra clay | 0 | 15 | 6.8 | 6 | 0 | |
| | | leached grey | 40 | 50 | 8.4 | 17 | 0 | |
| | | phase | 80 | 90 | 8.7 | 79 | 0.05 | |
| | | | 110 | 120 | 7.5 | 315 | 0.05 | **** |
| 24 | 1g | Cununurra clay | 0 | 5 | 7.5 | 5 | 0 | |
| | | leached grey | 20 | 30 | 8.5 | 32 | 0 | |
| | | phase | 60 | 70 | 9.0 | 18 | 0 | |
| | | | 110 | 120 | 7.7 | 208 | 0.04 | **** |
| | | | 170 | 180 | 7.9 | 339 | 0.03 | **** |
| | | | 300 | 310 | 8.1 | 79 | 0.03 | |
| 27 | 1c | Cununurra clay | 0 | 5 | 6.3 | 9 | 0 | |
| | | leached brown | 15 | 25 | 7.0 | 5 | 0 | |
| | | phase | 70 | 80 | 8.7 | 461 | 0.05 | |
| | | | 110 | 120 | 8.2 | 144 | 0.14 | |
| 33 | 1d | Cununurra clay | 0 | 5 | 7.0 | 8 | 0 | |
| | | leached | 20 | 30 | 8.1 | 5 | 0 | |
| | | grey-gypsic | 60 | 70 | 9.1 | 13 | 0 | |
| | | phase | 110 | 120 | 9.4 | 29 | 0 | |

| Site KNX | Map unit | Soil type | Depth upper (cm) | Depth lower (cm) | pH 1:5 water | EC 1:5 mS/m | Cl (%) | Sulphates present **** |
|---|---|---|---|---|---|---|---|---|
| 35 | 1e | Cununurra clay | 0 | 3 | 8.1 | 13 | 0 | |
| | | leached | 10 | 20 | 7.6 | 6 | 0 | |
| | | grey-gypsic | 50 | 60 | 8.1 | 9 | 0 | |
| | | phase | 100 | 120 | 7.5 | 392 | 0.08 | **** |
| 44 | 1d | Aquitaine | 0 | 5 | 6.9 | 5 | 0 | |
| | | greyish phase | 20 | 30 | 7.8 | 5 | 0 | |
| | | | 60 | 70 | 8.2 | 7 | 0 | |
| | | | 110 | 120 | 7.6 | 302 | 0.1 | **** |
| 55 | 1d | Cununurra clay | 0 | 5 | 7.2 | 9 | 0 | |
| | | leached grey | 20 | 30 | 7.6 | 4 | 0 | |
| | | phase | 70 | 80 | 8.8 | 25 | 0 | |
| | | | 110 | 120 | 8.4 | 40 | 0.03 | |
| 64 | 1d | Cununurra clay | 0 | 5 | 6.6 | 5 | 0 | |
| | | leached grey | 20 | 30 | 6.9 | 4 | 0 | |
| | | phase | 70 | 80 | 8.7 | 17 | 0 | |
| | | | 110 | 120 | 8.2 | 20 | 0 | |
| 83 | 1f | Cununurra clay | 0 | 10 | 7.3 | 5 | 0 | |
| | | leached | 10 | 30 | 7.9 | 5 | 0 | |
| | | brown-gypsic | 70 | 80 | 8.9 | 27 | 0 | |
| | | phase | 140 | 150 | 7.5 | 366 | 0.02 | **** |
| 96 | 1g | Cununurra clay | 0 | 10 | 6.4 | 4 | 0 | |
| | | leached grey | 10 | 20 | 7.2 | 4 | 0 | |
| | | phase | 50 | 60 | 7.7 | 320 | 0.04 | **** |
| | | | 110 | 120 | 8.8 | 56 | 0.04 | |
| 102 | 1c | Aquitaine | 0 | 5 | 7.0 | 17 | 0 | |
| | | greyish phase | 5 | 10 | 6.9 | 4 | 0 | |
| | | | 50 | 55 | 8.5 | 20 | 0 | |
| | | | 110 | 120 | 8.3 | 107 | 0.09 | |
| | | | 190 | 200 | 7.5 | 431 | 0.13 | **** |
| 108 | 1g | Cununurra clay | 5 | 15 | 7.3 | 5 | 0 | |
| | | leached grey | 50 | 60 | 7.9 | 67 | 0 | |
| | | phase | 110 | 120 | 7.7 | 357 | 0.05 | **** |
| | | | 180 | 200 | 7.5 | 385 | 0.08 | **** |
| 112 | 1c | Cununurra clay | 5 | 10 | 6.7 | 9 | 0 | |
| | | leached brown | 20 | 25 | 8.6 | 13 | 0 | |
| | | phase | 90 | 100 | 8.9 | 38 | 0 | |
| | | | 210 | 230 | 7.7 | 353 | 0.07 | **** |

# Appendix 7. EC values and textures of deep drilling samples

| DOME sample number ORD94 & AMG | Depth (m) | EC (1:5) mS/m @ 25°C | Field texture | DOME sample number ORD94 & AMG | Depth (m) | EC (1:5) mS/m @ 25°C | Field texture |
|---|---|---|---|---|---|---|---|
| **16** | 0-3 | 343 | MC | **31** | 0-3 | 204 | MHC |
| 499400mE | 3-6 | 143 | LMC | 499970mE | 3-6 | 36 | MC |
| 8278560mN | 6-9 | 159 | LMC | 8276593mN | 9-12 | 82 | LMC |
| | 9-12 | 72 | LC | | 12-15 | 38 | SCL |
| | 12-15 | 53 | SL | | 15-18 | 27 | LC |
| | 15-18 | 22 | LMC | | 18-21 | 18 | CS |
| | 18-21 | 29 | SCL | | 21-24 | 15 | SL |
| | 21-24 | 20 | LC | | 24-27 | 28 | CS |
| | 27-28.5 | 30 | SCL | **32** | 0-3 | 340 | MHC |
| **17** | 0-3 | 16 | SCL | 499868mE | 6-9 | 177 | CS |
| 499970mE | 3-6 | 42 | LMC | 8274732mN | 9-12 | 125 | MC |
| 8276593mN | 6-9 | 7 | LMC(ks) | | 12-15 | 94 | LC |
| | 9-12 | 4 | LS | | 15-18 | 134 | MC |
| | 12-15 | 4 | SCL | **33** | 0-3 | 8 | LS |
| | 15-18 | 5 | LC | 497877mE | 3-6 | 79 | MC |
| | 21-24 | 7 | SCL | 8281345mN | 6-9 | 89 | MC |
| | 27-30 | 50 | LMC(fs) | | 9-12 | 66 | MC |
| | 30-33 | 52 | MC | | 12-15 | 84 | MC |
| | 33-36 | 18 | MC | | 24-27 | 272 | MC |
| **30** | 0-3 | 195 | MC | **34** | 3-6 | 96 | SC(ks) |
| 496837mE | 3-6 | 180 | MHC | 498383mE | 6-9 | 137 | SC(ks) |
| 8279623mN | 6-9 | 255 | MC | 8278971mN | 9-12 | 238 | LMC |
| | 9-12 | 34 | MC | | 12-15 | 164 | MC |
| | | | | | 15-18 | 61 | SC |
| | | | | | 18-21 | 54 | LKS |
| | | | | | 21-24 | 28 | LKS |

**Textures**

| | |
|---|---|
| KS | Loamy sand |
| LKS | Loamy coarse sand |
| CS | Clayey sand |
| S | Sand |
| SCL | Sandy clay loam |
| (ks) | Coarse sandy |
| (fs) | fine sandy |
| LC | Light clay |
| SC | Sandy clay |
| LMC | Light medium clay |
| MC | Medium clay |
| MHC | Medium heavy clay |

# Recent Resource Management Technical Reports

| | | |
|---|---|---|
| **152** | **Soils of the Weaber Plain, East Kimberley, Western Australia** | **Jim Dixon** |
| **153** | **Soils of the Knox Creek Plain, East Kimberley, Western Australia and Northern Territory** | **Noel Schoknecht, Chris Grose, Dennis Fett, Stephen Johnston** |
| **154** | **Soils of the Mantinea Loop, Ord River Valley, East Kimberley, Western Australia** | **Noel Schoknecht, Chris Grose** |
| **155** | **Soils of the Ivanhoe West Bank, East Kimberley, Western Australia** | **Noel Schoknecht, Chris Grose** |
| **156** | **Assessment of the suitability for agriculture of the North west Packsaddle area, Kununurra** | **Noel Schoknecht** |
| **157** | **Assessment of the suitability for horticulture of the Packsaddle Infill area, Kununurra** | **Noel Schoknecht** |

**Soils of the Knox Creek Plain, East Kimberley, Northern Territory**
**Supplementary report**
**21 October 1998**

Noel Schoknecht
Agriculture Western Australia

**Summary**
A field review of the Northern Territory mapping of the Knox Creek Plain to more accurately define the extent of the cracking clay soils, and the extent and variability of the levee/lighter soils was conducted in October 1998 to supplement and improve the mapping done in 1994.

The review;

- amended and reduced the areas and occurrences of "levee" soils (map unit 7f) in the north of the study area;
- found that Aquitaine soils (mapped in 1994 as unit 5b) did not occur;
- identified increased soil variability in the south-west and south of the study area;
- noted the occurrence of some subtle undulations in surface topography in the south of the study area; and
- noted the frequent occurrence of numerous small areas subject to longer seasonal inundation in the cracking clay plain. These areas conspicuous as they are vegetated with the small tree gutta percha (*Exoecaria parviflora*) and have little understorey (few grasses) in the dry season.

**Introduction**

This report provides additional soils information for the Northern Territory part of the Knox Creek Plain. This additional work was funded by Wesfarmers – a partner in the feasibility study for Ord Stage 2 (M2 area).

The "study area" referred to in this report is the Northern Territory part of the Knox Creek Plain. The abbreviation AgWA refers to Agriculture Western Australia.

This report builds upon the previous information contained in the Resource Management Report No. 153, Soils of the Knox Creek Plain, Agriculture Western Australia, 1996. This report should be used as the source of all background information.

The purpose of this study was to:

- Undertake a field review of the Northern Territory mapping of the Knox Creek Plain to more accurately define the extent of the cracking clay soils, and the extent and variability of the levee/lighter soils. These issues are critical for the potential extent of the irrigable area, and irrigation layout design.
- Produce a supplementary report and map to document the new site data, mapping revisions and revised land capability assessment.

**Survey procedure:**

40 sites were described during the period 14-17 October 1998. Field examinations of the soils were conducted, and the soils were described for a minimum of horizons, texture, colour, structure, EC, pH, mottles and segregations. Depth of sampling was limited by the very dry and hard soils at the end of the dry season, and sampling was limited to less than 100 cm. In most cases this was sufficient to identify the soils and correlate them to soils described in more detail during the 1994 survey of Knox Creek plain.

In addition to the site data, the plain was traversed cross-country (not on tracks) several times to check the accuracy of the mapping, and revise soil boundaries.

**Results:**

Several amendments were made to the original mapping on the basis of the new sites and observations plus a review of the existing data. Significant variations to the original mapping are recommended. In summary the variations include:

- amendment and reduction of the areas and occurrences of "levee" soils (map unit 7f) in the north of the study area;
- deletion of Aquitaine soils (mapped in 1994 as unit 5b);
- and increase in soil variability in the parts of the south-west and south of the study area;

- the occurrence of some subtle undulations in surface topography in the south of the study area; and
- the frequent occurrence of numerous small areas subject to longer seasonal inundation in the cracking clay plain. These areas conspicuous as they are vegetated with the small tree gutta percha (*Exoecaria parviflora*) and have little understorey (few grasses) in the dry season.

**Map units**

Map units are as described in the Resource Management Report No. 153, Soils of the Knox Creek Plain, Agriculture Western Australia, 1996, with following modifications:

### *1d Greyish cracking clays; southern parts of the plain*

This unit dominates in the south of the Knox Creek Plain in WA and sporadically throughout the plain in the Northern Territory. It is a flat to very gently sloping plain which is occasionally traversed by minor depressions or flow pathways. Major depressions have been separated out in unit 1e. This is very similar to 1c, but with greyer clays.

The soils are mainly grey cracking clays with a weakly self-mulching surface, carbonates in the B horizon and frequent gypsum crystals below 1 m (Cununurra clay leached grey phase and Cununurra clay leached grey-gypsic phase). The subdominant soil is similar, but brown in colour (Cununurra clay leached brown phase and Cununurra clay leached brown-gypsic phase).

The unit also contains several minor depressions in the plain which are inundated for longer periods than adjacent areas of the plain, and are dominated by the small tree gutta percha (*Exoecaria parviflora*).

The native vegetation is mainly tall tussock grass shrub or tree savanna. Common tree or shrub species include *Eucalyptus microtheca, Exoecaria parviflora, Atalaya hemiglauca, Lysiphyllum cunninghamii, Terminalia volucris* and *Acacia* sp. *H.* Common grasses include *Aristida latifolia, Chrysopogon fallax, Iseilema vaginiflorum, Dicanthium spp.* and *Astrebla squarrosa.*

### *7bs Cracking clays in eroded and truncated condition and other soils bordering rivers and major creeks, surface often stony*

Sloping margins of the plains immediately adjacent to the major river or creek banks; severe natural erosion. Variable soils, often cracking clays which have been eroded or truncated. A stony surface is common.

**Soils**

Soils are as described in the Resource Management Report No. 153, Soils of the Knox Creek Plain, Agriculture Western Australia, 1996, with no modifications:

**Land use interpretation**

Suitability of map units for flood irrigation

Land use interpretations are as described in the Resource Management Report No. 153, Soils of the Knox Creek Plain, Agriculture Western Australia, 1996, with following modifications:

***Map unit 7bs***

These are river frontage areas which are often stony and are not suitable for irrigation.

## Suitability of soils for flood irrigated agriculture

**Table 3 Total area of each map unit in the survey area (WA and NT).**

| Map unit | Total (ha) |
|---|---|
| **1c** | 2800 |
| **1d** | 4398 |
| **1d/7f** | 175 |
| **1ds** | 64 |
| **1e** | 250 |
| **1e/7f** | 65 |
| **1f** | 273 |
| **1g** | 771 |
| **5b** | 16 |
| **5e** | 191 |
| **6b** | 373 |
| **6e** | 160 |
| **7a** | 230 |
| **7a/7b** | 638 |
| **7b1** | 111 |
| **7bs** | 20 |
| **7f** | 578 |
| **8a** | 129 |
| **11** | 719 |
| **11b** | 50 |
| **L** | 5 |
| **TOTAL** | 12016 |

**Table 4. Suitability of map units for flood irrigation**

| Map unit | Suitability | Limitations |
|---|---|---|
| **1c** | Suitable | Large areas of uniform brown or grey cracking clay |
| **1d** | Suitable | Large areas of uniform grey cracking clay |
| **1d/7f** | Marginally suitable | Complexity of soil types |
| **1ds** | Suitable | Surface rock to be removed |
| **1e** | Suitable | Drainage needs to be provided |
| **1e/7f** | Marginally suitable | Complexity of soil types |
| **1f** | Marginally suitable | Complexity of soil types |
| **1g** | Suitable | Large areas of uniform grey cracking clay |
| **5b** | Suitable | Surface drainage may be required<br>Some areas may be too small or isolated |
| **5e** | Not suitable | Soils unsuitable |
| **6b** | Unsuitable | Rock outcrop |
| **6e** | Unsuitable | Slopes, sandy soils, rock |
| **7a** | Unsuitable | Proximity to Keep River |
| **7b** | Unsuitable | Eroded and variable soils, close to Keep River |
| **7b1** | Unsuitable | Erodible and close to Keep River |
| **7bs** | Unsuitable | Erodible, stony and close to Keep River |
| **7f** | Marginally suitable | Very variable soils with variable chemical and physical properties |
| **8a** | Unsuitable | Poorly drained and variable soils |
| **11** | Unsuitable | Slopes, unsuitable sandy or texture contrast soils |
| **11b** | Unsuitable | Slopes and high infiltration rates |
| **L** | Unsuitable | Permanent water |

## Appendix 1. Site locations

In the Agriculture Western Australia's PROFILES database sites on the Knox Creek plain are numbered as follows:

- Sites described by the Conservation Commission of the Northern Territory during 1994 have been renumbered KNX1001 - KNX1030 (formerly KN01 – KN30).
- Sites examined in 1994 for the Western Australian part of the Knox Creek Plain are numbered KNX001 – KNX139.
- Sites described in the 1998 revision of the Northern Territory part of the Knox Creek Plain are numbered KNX201 - KNX240

The location of sites described by AgWA in 1998 are listed below. Detailed site information can be obtained from the PROFILES database, Natural Resources Assessment Group, AgWA. Noel Schoknecht (08) 9368 3707.

Sites KNX201 – KNX240. (All sites in zone 52L)

| Site no. | Easting (m) | Northing (m) | Site no. | Easting (m) | Northing (m) |
|---|---|---|---|---|---|
| KNX201 | 501046 | 8271983 | KNX221 | 502674 | 8268520 |
| KNX202 | 501571 | 8272135 | KNX222 | 503353 | 8268980 |
| KNX203 | 501862 | 8272132 | KNX223 | 503167 | 8274372 |
| KNX204 | 502571 | 8272072 | KNX224 | 502713 | 8274092 |
| KNX205 | 503004 | 8271467 | KNX225 | 502342 | 8273969 |
| KNX206 | 503203 | 8271052 | KNX226 | 502054 | 8273722 |
| KNX207 | 503285 | 8270876 | KNX227 | 502427 | 8273762 |
| KNX208 | 503543 | 8270574 | KNX228 | 501478 | 8273493 |
| KNX209 | 503449 | 8269543 | KNX229 | 500796 | 8272494 |
| KNX210 | 503245 | 8269375 | KNX230 | 500856 | 8276218 |
| KNX211 | 502648 | 8269129 | KNX231 | 503113 | 8275867 |
| KNX212 | 502024 | 8268885 | KNX232 | 502536 | 8275257 |
| KNX213 | 501722 | 8268431 | KNX233 | 502304 | 8275373 |
| KNX214 | 500774 | 8270547 | KNX234 | 500758 | 8274865 |
| KNX215 | 501778 | 8266795 | KNX235 | 500709 | 8270050 |
| KNX216 | 502021 | 8266939 | KNX236 | 501169 | 8269991 |
| KNX217 | 502377 | 8267214 | KNX237 | 501750 | 8270330 |
| KNX218 | 502233 | 8267609 | KNX238 | 501446 | 8271394 |
| KNX219 | 502353 | 8268396 | KNX239 | 501070 | 8271778 |
| KNX220 | 502443 | 8268592 | KNX240 | 501120 | 8272408 |