

ORD RIVER IRRIGATION AREA STAGE 2 PROPOSED DEVELOPMENT OF THE M2 AREA

Environmental Review and Management Programme

Draft Environmental Impact Statement

Prepared for:

**WESFARMERS SUGAR COMPANY PTY LTD,
MARUBENI CORPORATION AND
THE WATER CORPORATION OF
WESTERN AUSTRALIA**

C/- Level 7, 40 The Esplanade
Perth WA 6000

Prepared by:

Kinhill Pty Ltd

ACN 007 660 317

47 Burswood Road

Victoria Park WA 6000

January 2000

© Wesfarmers Sugar Company Pty Ltd, Marubeni Corporation, the Water Corporation of Western Australia, 1999.

Limitations Statement

In preparing this report, Kinhill Pty Ltd has relied upon and presumed accurate certain information (or absence thereof) relative to the site that was obtained from examination of records in the public domain or provided by government officials and authorities. Except as otherwise stated in the report, Kinhill has not attempted to verify the accuracy or completeness of any such information.

The findings, observations and conclusions expressed by Kinhill Pty Ltd in this report are not, and should not be considered, an opinion concerning the feasibility of establishing irrigated agriculture on the site. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon information in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Wesfarmers Sugar Company Pty Ltd, Marubeni Corporation and the Water Corporation of Western Australia, and is subject to and issued in connection with the provisions of an agreement with Kinhill Pty Ltd. Kinhill Pty Ltd accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

INVITATION TO MAKE A SUBMISSION

The Environmental Protection Authority (WA EPA) invites people to make a submission on this proposal.

Wesfarmers Sugar Company Pty Ltd, Marubeni Corporation and the Water Corporation of Western Australia propose the development of an export based raw-sugar industry involving development of the M2 Area of the Ord River Irrigation Area - Stage 2, a new raw-sugar mill and export facilities at the Port of Wyndham. The Western Australian (WA) and the Northern Territory (NT) Governments have agreed that the proposal to expand the Ord River Irrigation Scheme and develop the M2 Area should be jointly assessed using the WA environmental impact assessment process. It has also been agreed that the assessment should be as an Environmental Review and Management Programme (ERMP) (WA) and Environment Impact Statement (EIS) (NT). The ERMP/draft EIS, which has been prepared to describe this proposal and its likely effects on the environment, is available for a public review period of 10 weeks from **Monday 24 January 2000** closing on **Friday 31 March 2000**.

Comments from government agencies and from the public will help the WA EPA to prepare an assessment report in which it will make recommendations to government.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the WA EPA will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the Freedom of Information Act, and may be quoted in full or in part in the WA EPA's report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining with a group interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or groups, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the ERMP/draft EIS or the specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal more environmentally acceptable.

When making comments on specific element of the proposal:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable;
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- attempt to list points so that issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the ERMP/draft EIS;
- if you discuss different sections of the ERMP/draft EIS, keep them distinct and separate, so there is no confusion as to which section you are considering;
- attached any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name;
- address;
- date;
- whether you want your submission to be confidential.

The closing date for submissions is **Friday 31 March 2000**.

Submissions should be addressed to:

The Environmental Protection Authority
Westralia Square
141 St George's Terrace
PERTH WA 6000
Attention: Juliet Cole

Table of Contents

SUMMARY	Page		Page
1 PROJECT OBJECTIVES AND BACKGROUND	1-1	2.2.10 Commissioner for Soil and Land Conservation	2-7
1.1 The existing Ord River Irrigation Scheme	1-1	2.2.11 Ministry for Planning	2-8
1.1.1 History of development	1-1	2.2.12 Kimberley Development Commission	2-8
1.1.2 Existing development	1-2	2.2.13 Department of Conservation and Land Management	2-9
1.1.3 Potential for expansion	1-4	2.2.14 Department of Resources Development	2-9
1.1.4 Development preliminaries	1-5	2.2.15 Fisheries	2-9
1.2 The Project	1-6	2.2.16 Environmental Protection Authority	2-10
1.2.1 Project overview	1-6	2.2.17 Department of Environmental Protection	2-10
1.2.2 Products and markets	1-7	2.2.18 Shire of Wyndham – East Kimberley	2-11
1.3 The Proponents	1-9	2.2.19 Department of Land Administration	2-11
1.3.1 Co-proponents	1-9	2.3 Environmental issues and their management	2-12
1.3.2 Wesfarmers	1-10	2.3.1 Pesticide and chemical use	2-12
1.3.3 Marubeni	1-11	2.3.2 Groundwater issues	2-17
1.3.4 The Water Corporation	1-11	2.3.3 Surface water issues	2-18
1.4 The approvals process	1-12	2.3.4 Terrestrial and aquatic weeds	2-19
1.4.1 Western Australia and the Northern Territory regulatory framework	1-12	2.3.5 Environmental management framework	2-19
1.4.2 The environmental impact assessment procedure	1-12	2.4 Implications for the proposed development of the Project Area	2-22
1.5 Consequences of not proceeding with the Project	1-15	2.4.1 Pesticide and chemical use	2-22
1.5.1 Environmental consequences of not proceeding	1-15	2.4.2 Groundwater issues	2-23
1.5.2 The sugar market	1-17	2.4.3 Surface water issues	2-24
1.5.3 The State and national economies	1-18	2.4.4 Terrestrial and aquatic weeds	2-25
1.6 Scope and structure of the report	1-18	2.4.5 Environmental management framework	2-25
1.6.1 Scope	1-18	3 DESCRIPTION OF THE PROJECT	3-1
1.6.2 Structure	1-18	3.1 Project scope and timing	3-1
2 THE EXISTING ORD RIVER IRRIGATION AREA	2-1	3.1.1 Scope	3-1
2.1 Crops and Products	2-1	3.1.2 Relationship to other developments	3-2
2.2 Management Responsibilities	2-3	3.1.3 Programme	3-3
2.2.1 Farmers	2-3	3.2 Farm development and operation	3-4
2.2.2 Ord River District Co-operative	2-4	3.2.1 Farm development	3-4
2.2.3 Land and Water Management Plan Steering Committee	2-4	3.2.2 Ground preparation and planting	3-6
2.2.4 Ord Development Council	2-5	3.2.3 Sugarcane harvesting	3-6
2.2.5 Water and Rivers Commission	2-5	3.2.4 Farm management	3-7
2.2.6 Office of Water Regulation	2-5	3.2.5 Sugarcane research and development	3-7
2.2.7 The Water Corporation	2-6	3.3 On-farm Water Management	3-8
2.2.8 Ord Irrigation Co-operative	2-6	3.3.1 Crop water requirements	3-8
2.2.9 AGWEST	2-7	3.3.2 Tailwater management systems	3-9
		3.3.3 Crop drainage requirements	3-9
		3.3.4 Collection and discharge of stormwater	3-10

3.4	Farm Fertilisers, Chemicals and Their Use	3-10	5.2.3	Water allocation and licence provision	5-3
3.4.1	Sugarcane	3-10	5.3	Keep River, Sandy Creek and their tributaries	5-4
3.4.2	Other crops	3-12	5.3.1	Hydrology	5-4
3.5	Irrigation, Drainage and Flood Protection Infrastructure	3-12	5.3.2	Water quality	5-8
3.5.1	Irrigation infrastructure	3-12	5.4	Predicted changes to the hydrology of the Keep River	5-9
3.5.2	Drainage infrastructure	3-20	5.4.1	Influence of the flood protection levees	5-9
3.5.3	Flood protection infrastructure	3-20	5.4.2	Influence of improved drainage of the farm development area	5-13
3.6	Other Infrastructure	3-21	5.4.3	Alteration of dry season flow patterns	5-14
3.6.1	Roads	3-21	5.4.4	Influence of groundwater management strategies	5-14
3.6.2	Power	3-21	5.5	Water quality issues	5-15
3.6.3	Telecommunications	3-22	5.5.1	Construction activities	5-15
3.7	Sugar-Milling	3-22	5.5.2	Farm operations	5-16
3.7.1	Scope	3-22	5.5.3	Sugar mill effluents	5-18
3.7.2	Process description	3-22	5.5.4	Weed control in the irrigation channels	5-18
3.7.3	Effluents and emissions	3-24	5.5.5	Groundwater disposal	5-18
3.8	Processing of Other Crops	3-25	5.6	Predicted changes to water quality	5-19
3.9	Materials Handling and Transport	3-25	5.6.1	Water quality in the Keep River	5-19
3.9.1	Sugarcane transport	3-25	5.6.2	Water quality in Sandy Creek	5-20
3.9.2	Farm requirements	3-25	5.6.3	Water quality monitoring	5-20
3.9.3	Products	3-27			
3.10	Construction Issues	3-28	6	GROUNDWATER	6-1
3.11	Environmental management and monitoring system	3-29	6.1	Background	6-1
3.12	Alternative development scenarios	3-29	6.2	Regional Geology	6-2
3.12.1	Alternative crops	3-29	6.2.1	Basement geology	6-2
3.12.2	Partial development of the Project Area	3-30	6.2.2	Alluvial sediments	6-3
3.12.3	Conclusion	3-31	6.3	Regional Hydrogeology	6-4
4	PHYSICAL ENVIRONMENT	4-1	6.3.1	Groundwater flow	6-4
4.1	Climate	4-1	6.3.2	Groundwater quality	6-5
4.2	Geology	4-2	6.4	Management of accessions to groundwater	6-6
4.3	Landforms	4-3	6.4.1	Infrastructure	6-6
4.4	Soils	4-4	6.4.2	Cropping areas	6-7
4.5	Predicted impacts and their management	4-11	6.5	Groundwater Management Strategy	6-8
4.5.1	Landform	4-11	6.5.1	Groundwater modelling	6-8
4.5.2	Erosion	4-11	6.5.2	Groundwater recovery and disposal	6-9
4.5.3	Sedimentation	4-12	6.5.3	Predicted changes to groundwater levels	6-10
4.5.3	Soil chemical status	4-12	6.5.4	Predicted changes to groundwater quality	6-16
5	SURFACE WATER	5-1	6.5.5	Monitoring programme	6-17
5.1	Overview	5-1	7	EXISTING ENVIRONMENT—	
5.2	Ord River	5-1		TERRESTRIAL VEGETATION AND	
5.2.1	The Draft Interim Water Allocation Plan for the Ord River	5-2		FLORA	7-1
5.2.2	Assumptions made relating to the Draft Interim Water Allocation Plan	5-2			

7.1	Overview	7-1	9.4.2	Fish	9-7
7.1.1	The Victoria–Bonaparte Biogeographic Region	7-1	9.4.3	Crustaceans	9-9
7.1.2	Biological surveys in and adjacent to the Project Area	7-1	9.4.4	Molluscs	9-9
7.2	Vegetation in and adjacent to the Project Area	7-3	9.4.5	Insects	9-10
7.2.1	Vegetation mapping of the Project Area	7-4	9.4.6	Marine fauna	9-11
7.2.2	Comparison of the Project Area with portions of Auvergne and Spirit Hills stations	7-11	9.5	Stygofauna	9-11
7.2.3	Comparison of the Project Area with other areas	7-14	10	BIOLOGICAL ENVIRONMENT— IMPACTS AND MANAGEMENT	10-1
7.2.4	Conservation significance of the vegetation associations	7-15	10.1	Legislation and policy framework for environmental management	10-1
7.3	Flora of the Project Area	7-16	10.1.1	National strategies for environmental management and their implications for the Project	10-2
7.4	Introduced Flora	7-17	10.1.2	Requirements of the EPA	10-4
8	EXISTING ENVIRONMENT— TERRESTRIAL FAUNA	8-1	10.1.3	Native title implications	10-4
8.1	Review of biological surveys	8-1	10.1.4	Management of biodiversity in the Australian context	10-5
8.1.1	Regional overview	8-1	10.2	Existing and proposed reserves in the Victoria–Bonaparte biogeographic region	10-6
8.1.2	Fauna surveys of the East Kimberley	8-1	10.2.1	Current reserve system	10-6
8.1.3	Fauna of cracking-clay environments	8-2	10.2.2	Proposed reserve system	10-11
8.2	Fauna habitats of the Project Area	8-4	10.3	Conservation within the Project Area	10-12
8.2.1	Grassland	8-5	10.3.1	The need for conservation areas within the Project Area	10-12
8.2.2	Eucalyptus woodland	8-6	10.3.2	Conservation strategy for the Project Area	10-13
8.2.3	Riverine woodland	8-6	10.3.3	Protection of watercourses and rock outcrops	10-18
8.2.4	Vine thicket	8-8	10.3.4	Soil types	10-18
8.2.5	Wetland	8-8	10.3.5	Vegetation associations and flora	10-20
8.2.6	Rock outcrops	8-8	10.3.6	Native fauna and associated habitats	10-23
8.3	Vertebrate fauna	8-9	10.3.7	Comparison with other conservation proposals	10-25
8.3.1	Mammals	8-9	10.4	Assessment of potential impacts	10-26
8.3.2	Birds	8-10	10.4.1	Mammals	10-26
8.3.3	Reptiles and amphibians	8-11	10.4.2	Birds	10-28
8.4	Invertebrates	8-12	10.4.3	Reptiles	10-29
8.5	Rare and protected fauna	8-12	10.4.4	Frogs	10-29
8.6	Introduced Species	8-14	10.4.5	Fish and aquatic biota	10-29
9	EXISTING ENVIRONMENT— AQUATIC FLORA AND FAUNA	9-1	10.4.6	Insects	10-30
9.1	Overview	9-1	10.4.7	Stygofauna	10-31
9.2	Riparian vegetation	9-2	10.4.8	Interbasin water transfers	10-31
9.3	Aquatic vegetation and flora	9-4	10.4.9	Recovery plans for threatened species	10-32
9.3.1	Freshwater vascular flora	9-5	10.4.10	Existing conservation reserves	10-32
9.3.2	Seagrasses and macroalgae	9-6	10.4.11	National Wilderness	10-32
9.4	Aquatic fauna	9-7	10.4.12	Combined and cumulative impacts	10-33
9.4.1	Sponges	9-7	10.5	Environmental management	10-34

10.5.1	Vegetation associations and fauna habitats	10-34	12.3	Consultation with Miriung and Gajerrong People	12-2
10.5.2	Fire	10-34	12.4	Native Title and Land Rights Claims	12-5
10.5.3	Weeds	10-35	12.4.1	Background	12-5
10.5.4	Feral and pest animals	10-37	12.4.2	Native title claims	12-5
10.5.5	Public access	10-37	12.4.3	Aboriginal Land Rights claim	12-5
10.5.6	Borrow materials and rehabilitation	10-38	12.4.4	Native Title determination and appeal	12-6
10.5.7	Monitoring	10-38	12.4.5	Settlement of Native Title Issues in relation to the Project	12-6
11	LAND USE	11-1	12.5	Cultural Heritage	12-8
11.1	Historical European Land Use	11-1	12.5.1	Background	12-8
11.2	Current land use in and around the Project Area	11-2	12.5.2	Legislation relevant to Aboriginal cultural heritage in the Project Area	12-9
11.2.1	Agriculture	11-4	12.5.3	Strategy for the protection of cultural heritage	12-10
11.2.2	Mining	11-5	12.5.4	Cultural heritage assessments of the Project Area	12-11
11.2.3	Fishing and aquaculture	11-6	12.5.5	Archaeological analysis	12-12
11.2.4	Tourism and recreation	11-8	12.5.6	Cultural heritage fieldwork completed in 1998	12-14
11.2.5	Transportation	11-9	12.5.7	Further cultural heritage assessment	12-17
11.2.6	Conservation reserves	11-9	12.5.8	Managing cultural heritage	12-17
11.2.7	Population and settlements	11-10	12.6	Aboriginal Social Impact	12-19
11.2.8	Port of Wyndham	11-10	12.6.1	Background	12-19
11.3	Regional development and land-use control	11-10	12.6.2	Framework for the process	12-21
11.3.1	Strategic planning	11-10	13	AIR QUALITY AND NOISE	13-1
11.3.2	Statutory planning	11-11	13.1	Regional meteorology	13-1
11.4	Land Tenure within the Project Area	11-12	13.2	Dust	13-4
11.4.1	Developed land	11-13	13.3	Smoke and ash	13-4
11.4.2	Sugar mill site and airstrip	11-13	13.3.1	Cane-burning	13-4
11.4.3	Construction camp/workers camp	11-13	13.3.2	Land-clearing impacts and their management	13-6
11.4.4	Conservation area	11-13	13.4	Emissions from the sugar mill	13-6
11.4.5	Airstrips	11-13	13.5	Greenhouse gas emissions	13-7
11.4.6	Roads	11-13	13.5.1	Background	13-7
11.4.7	Irrigation, drainage and flood protection infrastructure	11-14	13.5.2	Effects of initial development	13-8
11.4.8	Powerlines and associated infrastructure	11-14	13.5.3	Effects of ongoing operations	13-9
11.4.9	Communications sites	11-14	13.6	Noise	13-11
11.5	Land-use impacts and mitigation measures	11-14	14	PUBLIC HEALTH	14-1
11.5.1	Pastoral uses	11-14	14.1	Mosquito-borne diseases	14-1
11.5.2	Tourism, recreation and conservation reserves	11-15	14.1.1	Background	14-1
11.5.3	Other issues	11-16	14.1.2	Monitoring for mosquito-borne diseases	14-2
12	ISSUES SPECIFIC TO MIRIUNG AND GAJERRONG PEOPLE	12-1	14.1.3	Management of impacts related to the Project	14-3
12.1	Introduction	12-1	14.2	Farm chemicals in the environment	14-5
12.2	Historical Overview	12-1	14.2.1	Overview	14-5

14.2.2	Commonwealth, State and Territory controls	14-5	16.4.2	Outline of the Proposed Environmental Management Framework	16-8
14.2.3	Industry management measures	14-7	16.5	Environmental Management Plan	16-13
14.2.4	Management measures proposed for the Project	14-7	16.6	Environmental Compliance/Regulatory Review	16-13
15	COMMUNITY ISSUES	15-1	16.7	Alternative Options for Management	16-14
15.1	Existing social environment	15-1	17	ENVIRONMENTAL MANAGEMENT COMMITMENTS	17-1
15.1.1	The Kimberley region	15-1			
15.1.2	Shire of Wyndham – East Kimberley	15-2			
15.2	Existing regional economy	15-6			
15.3	Workforce and population projections	15-8			
15.3.1	Characteristics of the existing workforce	15-8			
15.3.2	Project workforce	15-10			
15.3.3	Local population projections	15-10			
15.4	Social impact assessment	15-12			
15.4.1	The Kununurra–Wyndham Area Development Strategy	15-12			
15.4.2	Housing development	15-12			
15.4.3	Infrastructure expansion	15-13			
15.4.4	Public services	15-15			
15.4.5	Regional recreational resources	15-16			
15.4.6	Towns in the Northern Territory	15-17			
15.4.7	Construction workforce issues	15-17			
15.5	Community consultation	15-17			
15.5.1	Consultation objectives	15-17			
15.5.2	Consultation activities	15-18			
15.5.3	Proposed management measures for key issues	15-19			
16	ENVIRONMENTAL MANAGEMENT FRAMEWORK	16-1			
16.1	The Need for an Environmental Management Framework	16-1			
16.2	Relevant Legislative Issues	16-2			
16.3	Environmental Management Frameworks for Irrigation Projects in Australia	16-3			
16.3.1	Ord River Irrigation Area Stage 1	16-3			
16.3.2	South West Irrigation	16-3			
16.3.3	Burdekin River Irrigation Area	16-4			
16.3.4	Murray Irrigation Limited	16-4			
16.3.5	Goulburn Murray Water	16-5			
16.3.6	Coleambally Irrigation Corporation	16-5			
16.3.7	The Murray–Darling Basin Commission	16-6			
16.4	The Proposed Environmental Management Framework for the Project	16-8			
16.4.1	The Case for Self-Management	16-8			

APPENDICES

Appendix A	ERMP/draft EIS Guidelines
Appendix B	Glossary
Appendix C	Abbreviations
Appendix D	References
Appendix E	Organisations consulted during ERMP/draft EIS preparation
Appendix F	Study Team
Appendix G	Water Quality Data
Appendix H	Water Infiltration Modelling
Appendix I	Groundwater Report
Appendix J	Biological and Fauna Surveys of the Proposed Development Area
Appendix K	Terrestrial Biological Assessment
Appendix L	Keep River Aquatic Fauna Survey
Appendix M	Groundwater Fauna Sampling in the Kimberley
Appendix N	Cultural Heritage Protection Procedures
Appendix O	Outline Environmental Management Plan

Appendices G-O are separately bound in Volume 2.

ILLUSTRATIONS

	Page		Page
1.1	Overview of Ord Region and Project Area	1-3	
1.2	World sugar prices	1-9	
1.3	Environmental Impact Assessment Process Flow Chart	1-13	
3.1	Indicative Development Schedule	3-3	
3.2	Farm Unit Layout	3-5	
3.3	Conceptual tailwater return system	3-11	
3.4	Infrastructure–Weaber Plain	3-13	
3.5	Infrastructure–Keep River Plain	3-15	
3.6	Infrastructure–Knox Creek Plain	3-16	
3.7	Typical supply channel cross section and siphon structure	3-18	
3.8	Raw sugar milling process	3-26	
3.9	New storage facilities within the Wyndham Port	3-27	
4.1	Average climatic data for Kununurra	4-2	
4.2	Land Systems surrounding the Project Area	4-5	
4.3	Soils of the Project Area	4-9	
4.4	Relationship between Poned Infiltration Rate and ESP	4-14	
5.1	Regional Hydrology	5-5	
5.2	Predicted flood hydrographs	5-11	
6.1	Conceptual dewatering bore layout	6-11	
6.2	Groundwater management zones	6-13	
7.1	Vegetation associations of the Weaber Plain	7-5	
7.2	Vegetation associations of the Keep River Plain	7-7	
7.3	Vegetation associations of the Knox Creek Plain	7-8	
7.4	Selected vegetation communities of the Project Area	7-9	
8.1	Map of fauna survey sites in the Project Area	8-3	
8.2	Fauna habitats in the Project Area	8-7	
9.1	Wetlands surveyed by Benson within the Project Area	9-3	
10.1	Victoria–Bonaparte Biogeographic Region – existing and proposed land uses	10-7	
10.2	Conservation areas in the Project Area	10-15	
10.3	The Scenario 3 design of Woinarski and Connors (1997)	10-27	
11.1	Land use in the vicinity of the Project Area	11-3	
11.2	Mining permits in the Project Area	11-7	
12.1	Consultation with Miriung and Gajerrong people in the Project Area on 22 July 1998	12-4	
12.2	Miriung and Gajerrong Traditional Owner examining fauna caught during the flora and fauna survey	12-4	
12.3	Native Title and land rights claims associated with the Project Area	12-7	
12.4	Hillary Rumley and Miriung and Gajerrong people undertaking the Work Programme Clearance (photo courtesy Hillary Rumley)	12-15	
12.5	Cave Springs	12-16	
12.6	Jack Trust, Waringarri machine operation during the 1998 geotechnical investigation work	12-16	
12.7	View of Milligan Lagoon	12-18	
15.1	Male age structure in the Kimberley region in comparison with the whole of Western Australia	15-3	
15.2	Female age structure in the Kimberley region in comparison with the whole of Western Australia	15-3	
15.3	Age structure of Kimberley females in the Aboriginal community	15-4	
15.4	Age structure of Kimberley males in the Aboriginal community	15-4	
15.5	Camp workforce numbers	15-11	

	Page
16.1 Murray-Darling basin environmental management framework	16-7
16.2 Ownership of the proposed Environmental Management Entity	16-12
16.3 Structure of the Environmental Management Entity	16-12
16.4 Resourcing of the Environmental Management Entity Operations	16-12

TABLES

		Page		Page
1.1	Proposed land uses within the Project Area	1-7		
1.2	Regional world sugar production	1-8		
1.3	Relevant legislation, treaties and agreements	1-14	5.8	Creek peak flood height and peak average velocity
1.4	Report structure	1-19		5-12
			5.8	Comparison of nutrient levels in ORIA Stage 1 drains and the Keep River
				5-19
			5.9	Outline water quality monitoring programme
				5-21
2.1	ORIA Stage 1—value of production 1997–98	2-1	6.1	Estimated long-term dewatering rates
				6-9
2.2	Estimated crop areas in ORIA Stage 1 (ha)	2-2	6.2	Groundwater management classification system
				6-12
2.3	Insect, Weed and Disease control chemicals in recent use on farmland in ORIA Stage 1	2-13	6.3	Predicted maximum groundwater-induced discharges to non-tidal portions of watercourses
				6-15
3.1	Scope of the Project	3-2	7.1	Published biological information* for the region
				7-2
3.2	Estimated in-field water requirements for irrigated crops in the ORIA	3-8	7.2	Fine Scale Vegetation Units represented in the Project Area (Connors et al. 1996)
				7-4
3.3	Sugar-mill crushing volume	3-22	7.3	Vegetation communities and associated soil units within the Project Area
				7-12
4.1	General soil profiles and Great Soil Groups in Land Systems within or close to the Project Area	4-4	7.4	Broad vegetation groups of the Project Area and the Auvergne region
				7-13
4.2	Selection of soil's physical and chemical properties within the Project Area	4-7	7.5	Conservation codes and distribution of taxa recorded within the Project Area
				7-18
4.3	Guidelines for cropping	4-8	7.6	Flora of particular or listed conservation significance in the Project Area
				7-19
4.4	Soil salinity (EC _e) and ESP levels under various blocks in ORIA Stage 1	4-13	7.7	Occurrence of significant flora of the Project Area in Western Australia and the Northern Territory
				7-19
4.5	Effect of cropping history on ESPs of Cununurra clay	4-13	7.8	Declared weeds recorded within the Project Area
				7-20
5.1	The use of water released or flowing from Lake Argyle – for full irrigation development and the generation of 100GWhr of hydro-power per year	5-3	8.1	Vertebrate fauna of cracking-clay soils
				8-4
5.2	Keep River catchment areas	5-6	8.2	Fauna habitats in the Project Area
				8-5
5.3	DLPE stream flow recording	5-6	8.3	Summary of vertebrate fauna species* recorded in habitats of the Project Area
				8-9
5.4	Recorded monthly flows in Keep River at Legune Road Crossing	5-7	8.4	Rare and specially protected fauna known or predicted to occur in the Project Area
				8-13
5.5	Range of water quality data for the Keep River and associated waterholes	5-10	9.1	Wetland classification of the plans in the Project Area
				9-2
5.6	Range of water quality data for other watercourses	5-10	9.2	Riparian vegetation of wetlands in or near to the Project Area
				9-4
5.7	Summary of the influence of flood protection levees on Keep River and Border		9.3	Freshwater vascular plant species recorded in the vicinity of Kununurra
				9-5

9.4	Macroalgae collected from the Cambridge Gulf, northern Kimberley	9-7	12.1	Proportion of the Keep River Plain by archaeological sensitivity class	12-13
9.5	Distribution of endemic species of freshwater inland fishes in Western Australia	9-8	12.2	Proportion of the Knox Creek Plain of each archaeological sensitivity class	12-13
9.6	Habitat types and occurrence of mollusc species in the Ord River region	9-10	13.1	Wind direction frequency distribution (% at 9 a.m.) at Kununurra Airport, 1986–98	13-1
9.7	Insect species recorded in or near to the Project Area	8-11	13.2	Wind direction frequency distribution (% at 3 p.m.) at Kununurra Airport, 1986–98	13-2
9.8	Marine fauna recorded in the northern Kimberley	9-11	13.3	Wind speed frequency distribution (% at 9 a.m.) at Kununurra Airport, 1986–98	13-2
10.1	Conservation management legislation	10-1	13.4	Wind speed frequency distribution (% at 3 p.m.) at Kununurra Airport, 1986–98	13-3
10.2	Vegetation types in the Northern Territory portion of the Victoria–Bonaparte Biogeographic Region and their representation within reserves	10-9	13.5	Additional climatic data for Kununurra	13-3
10.3	Existing conservation reserves and wetlands included on the Ramsar List of Wetlands of International Importance within the Victoria–Bonaparte Biogeographic Region and adjoining areas	10-10	13.6	Summary of positive and negative aspects associated with cane-burning	13-5
10.4	Environmental features of Conservation Reserves and Ramsar Convention listed wetlands within the Victoria–Bonaparte Biogeographic Region	10-11	13.7	Potential sources of greenhouse gases and carbon sinks for the Project	13-8
10.5	Representation of each soil type in the development area and in the conservation area	10-19	13.8	Minimum total carbon stored in the Project Area for the existing and development scenarios*	13-9
10.6	Representation of vegetation associations in the development area and conservation areas (vegetation mapped area only)	10-21	13.9	Estimated greenhouse gas balance during project operations	13-10
10.7	Representation of rare and priority species within conservation areas within the Project Area	10-23	14.1	Significant arbovirus groups in Australia	14-1
10.8	Representation of fauna habitats in the development area and conservation areas (see Section 8.2)	10-23	15.1	Population, employment and household income in the Kimberley region	15-2
10.9	Preferred habitat of rare and specially protected fauna	10-24	15.2	Population trends for Kununurra and Wyndham	15-5
10.10	Environmental invasiveness and impacts of weeds in the Project Area	10-36	15.3	Kimberley region economic summary	15-6
11.1	Mining and exploration permits in the vicinity of the Project Area	11-6	15.4	Employment by occupation in the Shire of Wyndham – East Kimberley	15-9
11.2	Oil and gas permits intersecting with the Project Area	11-6	15.5	Estimated profile of additional workforce and resulting population increase	15-11
11.3	Vehicle numbers entering Western Australia via the Kununurra Quarantine Checkpoint, 1994	11-9	15.6	Accommodation requirements for additional workforce	15-13
11.4	Preferred land tenure within the Project Area	11-12	15.7	Media outlets utilised in the community consultation programme	15-18
			15.8	Summary of key issues raised during community consultation	15-20
			17.1	Summary of key commitments relating to the environmental management	17-2

Summary

A joint venture between Wesfarmers Sugar Company Pty Ltd (Wesfarmers) and Marubeni Corporation (Marubeni) was awarded an exclusive mandate in April 1998 by the Western Australian and Northern Territory Governments to investigate the feasibility of development of an area of land adjoining the existing Ord River Irrigation Area (ORIA).

The proposal being considered by Wesfarmers and Marubeni involves the potential establishment of a raw-sugar industry. The industry may involve the development of farmland for the purposes of growing sugarcane, the development of a sugar mill, and the development of storage facilities at the port of Wyndham. In parallel with the feasibility study being conducted by Wesfarmers and Marubeni, the Water Corporation of Western Australia (Water Corporation) is investigating the feasibility of development of the irrigation infrastructure required to service the farmland.

Neither of the abovementioned feasibility studies is complete, and at this stage no commitment, conditional or otherwise, has been made to proceed with the proposed development.

A key element of the feasibility studies is the acceptance or otherwise of the proposed development from an environmental perspective. For this reason, the proposal has been submitted for formal environmental review prior to the conclusion of the feasibility studies.

Due to the importance of water related issues to the environment, and the integrated nature of the proposed sugar industry and the irrigation infrastructure, Wesfarmers–Marubeni and the Water Corporation have undertaken to be the Co-proponents of a single and joint environmental assessment of the proposed development.

1 PROJECT OBJECTIVES

Development Preliminaries

Despite the completion of the Ord River Dam in 1972, the Ord River Irrigation Area (ORIA) has not yet been developed to its full potential. In 1994, the Western Australian Government decided to investigate the extension of the scheme and, as part of the fully developed scheme would lie within the Northern Territory, an agreement was reached between the Western Australian Government and the Northern Territory Government (the Governments) to jointly pursue the development. The extension to the existing scheme is known as ORIA Stage 2.

Throughout 1995 and 1996, the Governments commissioned various preliminary studies in relation to the expansion of the ORIA, with a view to private sector involvement. A call for expressions of interest in 1997 stimulated great interest from the private sector, and resulted in the submission of a number of detailed proposals from local and overseas-based organisations. In 1998, a joint venture between Wesfarmers and Marubeni was awarded an exclusive mandate by the Governments to investigate the feasibility of development of a portion of ORIA Stage 2 known as the M2 Development Area.

Scope of the Project

The proposed Project involves the development of an export-based raw-sugar industry on the Weaber, Keep River and Knox Creek plains in Western Australia and the Northern Territory. Key features of the Project are:

- sugarcane plantation development by Wesfarmers-Marubeni of approximately 29,000 hectares with potential for future 'sell-down' to independent farmers as smaller farms;
- the development of a raw-sugar mill by Wesfarmers-Marubeni with a capacity of approximately 400,000 tonnes per annum of raw-sugar and 160,000 tonnes per annum of molasses;
- the development by Wesfarmers-Marubeni of raw-sugar and molasses storage and handling facilities at Wyndham port;
- the sale of some 3,000 hectares of land by Wesfarmers-Marubeni to independent farmers on an unconditional basis with respect to the types of crops that may be grown. The commitments made in this report would also apply to this land;
- the development of irrigation, drainage and flood protection infrastructure by the Water Corporation;
- the establishment and management of over 40,000 hectares of land for conservation purposes.

Following development, the Project Area would therefore include approximately 32,000 hectares of land developed for farms, development of a further 3,000 hectares of land for infrastructure, and over 40,000 hectares of land managed for conservation. Farm areas would be developed on the heavy clay soils (black soils), while the land managed for conservation would include those areas that contain flora and fauna of conservation

significance on the black-soil and other areas, including riparian and rocky areas, within and around the farmland.

Major issues

The Project represents a significant opportunity for regional development in Australia and, in particular, in the East Kimberley. Due to the scale of the proposed development, a range of issues has had to be addressed during project planning. These issues include:

- the relationship of the Project to existing developments in the ORIA;
- potential changes to the hydrology of the Keep River;
- sustainable groundwater management;
- the conservation of the biological diversity of the region;
- changes in land use and compatibility with traditional uses by native title holders and claimants;
- Australia's targets for limiting greenhouse gas emissions under the Kyoto Protocol;
- the effect of the Project on mosquito-borne diseases in the region;
- the social implications of the consequential expansion of Kununurra;
- environmental management, including cross-border issues and conservation management.

The growing of sugarcane and its subsequent milling to produce raw sugar and molasses are operations that have been practised in Australia for many years. The Project offers the opportunity to incorporate recent advances in agricultural technology and productivity that would lead to improved management of off-farm impacts and water conservation.

This Environmental Review and Management Programme/draft Environmental Impact Statement (ERMP/draft EIS) demonstrates how the predicted biophysical and social environmental issues arising from the Project would be managed.

History of development

Development of the ORIA was originally planned to proceed in two stages. Stage 1 of the development was completed by 1966: this involved construction of the Kununurra Diversion Dam to form Lake Kununurra, as well as irrigation infrastructure and associated works, and the township of Kununurra.

The second stage of the ORIA has only been partially completed. Completed works include construction of the Ord River Dam - about 50 kilometres upstream from Kununurra - to provide a major storage reservoir called Lake Argyle. The Ord River Dam was officially opened in 1972.

In 1994 the height of the spillway in the Ord River Dam was raised as part of the works associated with the installation of a hydroelectric power station. The Ord River Dam is capable of supplying the water requirements for all ORIA Stage 2, the hydroelectric power station and the existing irrigation area.

The approvals process

A Memorandum of Understanding was signed on 19 April 1995 by the Chief Minister of the Northern Territory and the Premier of Western Australia in response to the desire of both their Governments to complete the ORIA. The Memorandum of Understanding provides a framework for sharing information from studies into the scheme and for planning by agencies of the two Governments and by the private sector.

The Governments of Western Australia and the Northern Territory have agreed that the Project should be subjected to joint environmental assessment and that the level of the assessment would be an ERMP in Western Australia and an EIS in the Northern Territory. Guidelines for the ERMP/draft EIS were finalised in July 1999.

The ERMP/draft EIS is available for comment by the public and by Government departments and agencies for a period of ten weeks. During this time members of the public are invited to forward comments on any aspect of the proposal to the Western Australian Environmental Protection Authority (EPA).

The EPA will prepare a summary of the public submissions for comment by Wesfarmers-Marubeni and the Water Corporation. Following receipt of these comments the relevant State and Territory Government departments and agencies will assess the proposal and publish the results in assessment reports.

In Western Australia, the ERMP and subsequent advice from the EPA will be considered by the Western Australian Minister for the Environment when making a decision in relation to the proposal. In the Northern Territory, the EIS will form the basis for recommendations that the Minister for Lands, Planning and Environment may make to the Northern Territory Cabinet on the Project.

Scope and structure of the report

The scope of the ERMP/draft EIS covers the environmental implications of the Project in response to the ERMP/draft EIS guidelines issued by the State and Territory Governments.

The ERMP/draft EIS does not visit issues associated with the construction and operation of the existing irrigation scheme (ORIA Stage 1). However, observations of past and current experiences in relation to ORIA Stage 1 have been utilised in the design and planning of the Project so as to improve the environmental performance. The ERMP/draft EIS also does not include issues associated with the water resource allocation from the Ord River as there is already an assessment of this issue being undertaken by the Water and Rivers Commission of Western Australia and the EPA.

Two key considerations have shaped the structure of the ERMP/draft EIS: the need to describe the scale and physical characteristics of the Project in the most effective way, and the need to examine those environmental factors that have been identified as being the most relevant in assessing the environmental impacts of the Project.

2 THE EXISTING ORD RIVER IRRIGATION AREA

ORIA Stage 1 comprises a gross area of 14,000 hectares of land developed for irrigated agriculture on the Ivanhoe Plain and the Packsaddle Plain. About 11,500 hectares of this area are cropped, with the balance devoted to irrigation, drainage and road infrastructure, and on-farm development. Agricultural activities include broad-acre cropping of the cracking clay (black-soil) areas with sugarcane, chick pea, pasture, melons and seed crops, and tree crops such as bananas and mangoes on the loam and sandy soils.

Early development of ORIA Stage 1 was beset with problems associated with control of pests which had a detrimental effect on farm economics. Current farming activities have benefited from the experience gained during those difficult early years to the extent that they are now profitable. As a consequence, there is now a shortage of developed irrigation farmland in the region.

Environmental issues and their management

ORIA Stage 1 has been operated continuously for the purpose of irrigated agriculture since 1963. Over that period, a wide range of commercial crops has been grown and farm management practices has evolved in response to the new crops, improved knowledge of local conditions, and improvements in agricultural practices generally.

The ongoing practice of irrigated agricultural in ORIA Stage 1 provides evidence that the environmental impacts are manageable in key areas such as pesticide and chemical usage, and the containment of groundwater, salinity, sedimentation and weed infestation.

One of the major changes in agricultural practices has been in the use of pesticides and chemicals. Current practices are profoundly different from those of the early development period of ORIA Stage 1, when the use of agricultural chemicals was extensive. The current use of chemicals has been tempered by lessons learnt from past practices, a shift in the mix of crops towards crops which are less reliant on chemicals, and the implementation of an integrated pest management strategy. However, the integrated strategy has reduced but not eliminated the continued application of a variety of agricultural chemicals deemed necessary to maintain the agricultural and commercial viability of ORIA Stage 1.

Large areas of sugarcane have been grown in ORIA Stage 1 in recent years. Sugarcane has a low requirement for chemicals compared with other broad-acre crops, and this has reduced the risks associated with off-farm impacts.

In common with other irrigated agricultural schemes, groundwater levels have risen over a significant proportion of the area covered by ORIA Stage 1. However, it is noted that after more than thirty years of irrigation, in only two localised areas is groundwater now less than 2 metres from the surface. Groundwater levels have not affected land use in ORIA Stage 1 to date and groundwater remedial measures have not been required. The monitoring data also show that no areas in ORIA Stage 1 have been affected by salinity, and groundwater salinity levels are generally within the range tolerated by most crop species.

Nevertheless, groundwater levels in ORIA Stage 1 may require management at some point in the future. Various options are available to provide such management, including extraction of groundwater from permeable gravel beds via dewatering bores, installation of subsurface drains, tree planting and improved farm drainage systems.

Drainage waters from ORIA Stage 1 containing varying quantities of sediment, nutrients and farm chemicals are discharged into the Ord River. As expected, measured nutrient levels downstream of the drain discharges are above natural levels. However, the low natural level of nutrients in the Ord River and the significant dilution provided from river flows obviate the occurrence of water quality problems in the lower Ord River.

A number of chemicals detected by water quality monitoring are no longer in use in ORIA Stage 1, including dieldrin, chlordane, heptachlor and DDT. While levels of these chemicals in the drains are currently above guidelines applicable to receiving waters, their concentration should continue to reduce with time.

The Ord River is currently free of any introduced aquatic weeds. However, the control in water levels brought about by the irrigation scheme infrastructure has led to proliferation of a *Typha* species (cumbungi) in Lake Kununurra and along the banks of the lower Ord River. This growth reduces access to the water's edge, interferes with navigation, and restricts the ability of farmers to pump directly from Lake Kununurra.

ORIA Stage 1 was developed before environmental legislation existed in Western Australia. As a consequence, no single environmental management plan was developed for ORIA Stage 1 in its entirety, and no holistic plan exists at the present time. Environmental management in ORIA Stage 1 currently relies upon the compliance of all individuals, groups and agencies with laws and statutes that apply to prevent pollution and degradation of land. This approach is common for broad-acre agricultural activities throughout Australia.

The local community has taken the initiative in preparing a Land and Water Management Plan to address the environmental issues and ensure long-term sustainability of ORIA Stage 1. The Land and Water Management Plan is to address the potential impacts, both environmental and economic, of uses of the land and water resources of ORIA Stage 1. The output from the Land and Water Management Plan is to be a framework for the implementation of appropriate environmental management practices and will result in an increased awareness and understanding of environmental issues by farmers and the wider community.

Implications for the Project Area

There are a range of opinions on the status of the environment in and surrounding ORIA Stage 1. Some argue that environmental issues are being managed in a pragmatic fashion, whilst others take the view that existing environmental issues should be resolved completely prior to any expansion of ORIA Stage 1 and/or development of ORIA Stage 2 (including the Project Area).

It is the view of Wesfarmers-Marubeni and the Water Corporation that development of the Project Area can be managed in an environmentally sustainable manner. However, it

is only natural that any expansion should take into account environmental issues that have become apparent during the implementation of ORIA Stage 1.

Experience from ORIA Stage 1, and from other irrigation areas around Australia, has shown that on-farm management of irrigation and stormwater is required in order to manage the off-farm impacts of pesticides and other agricultural chemicals. For this reason, current best-practice on-farm water management measures are proposed for the Project.

All farm units in the Project Area would be developed with tailwater return systems capable of collecting and returning all irrigation water runoff to each farm. The tailwater return systems have been designed in such a way as to perform the function of first-flush stormwater collection systems, with that stormwater to be retained on-farm for use as irrigation water. That is to say, that the tailwater return systems have been designed with the capacity to collect the initial farm runoff from rainfall events.

Recent advances in pesticide use and management in ORIA Stage 1 would be adopted and, wherever possible, enhanced in the Project Area.

In addition, the above management measures would be supported by a comprehensive monitoring programme for pesticides and chemicals in the receiving environment. The monitoring programme would be undertaken as part of the environmental management framework for the Project Area, and the results may be used to modify proposed on-farm practices if necessary.

A proactive groundwater management strategy is proposed as part of the Project. This strategy would manage groundwater levels from project inception to ensure the sustainability of irrigated agriculture on the Project Area.

An important lesson learned from the experiences with ORIA Stage 1 is that clear responsibility for groundwater management would be required, together with the allocation of responsibility for the funding of groundwater control measures. The Project has an advantage over ORIA Stage 1 in that current expectations with regard to environmental management can be incorporated into development plans from the outset. An environmental management framework would be established at project inception to ensure that environmental management responsibilities are clearly identified and appropriately implemented and funded as part of the Project.

The proposed environmental management framework has been developed in accordance with the concept of audited self-management. However, the proposed framework does allow for a high level of community input and regulatory authority review.

3 DESCRIPTION OF THE PROJECT

The proposed Project involves the development of an export-based raw-sugar industry on the Weaber Plain, the Keep River Plain and the Knox Creek Plain. The development would include approximately 29,000 hectares of sugarcane plantations, the necessary irrigation infrastructure to service the farmland, a 400,000 tonnes per annum raw-sugar mill, and storage and handling facilities at Wyndham port. A further 3,000 hectares would be made available for sale to independent farmers on which to grow crops of their choice; these crops may or may not include sugarcane.

Various alternative development scenarios were considered by Wesfarmers-Marubeni during preparation of the Project proposal. These included the potential development of part or all of the Project Area for the cultivation of crops other than sugarcane. However, it is the view of Wesfarmers-Marubeni that the proposed development scenario is the most robust of all the options, from an agronomic, economic, community and environmental perspective.

The Project would essentially be independent of other irrigation developments in the region, and require the development of purpose-built irrigation infrastructure for the distribution of water from the existing dams. ORIA Stage 1 is served by the M1 Channel. The Project Area would be serviced by the proposed M2 Channel, which would be aligned with the M1 Channel for the first 23 kilometres of its length from the off-take at Lake Kununurra. The M2 Channel would have a stand-alone management and operation system.

The development schedule would be staged to maximise the delivery of cane to the sugar mill in the early years. Farm development would be substantially complete by 2003 and the first cane would be harvested for processing by the mill in the same year. Full cane production should be achieved in 2005.

Farm development and operation

Initially, some 29,000 hectares of the total irrigable area would be developed and owned by Wesfarmers-Marubeni and operated as a sugarcane plantation. The plantation would be designed to facilitate the operation of large-scale farm equipment to optimise economies of scale.

Farm development would commence with the clearing of vegetation. Survey and land-levelling activities, which would optimise the cut-and-fill balance, would follow the land clearing. Farm development would then proceed with the construction of access roads, head ditches, tailwater return systems and stormwater drainage outlets.

Ground preparation prior to planting would generally involve spraying with a herbicide for the control of weeds, followed by cultivation to disturb any compaction from the previous construction activities.

The Project would utilise modern cane-planting machines that combine the planting operations in one pass-furrow-forming, fertiliser application, placement of the cane billets or stalks in the furrow, closing of the furrow and pressing of the soil on to the cane 'set'. It is envisaged that planting of new sugarcane crops would only be required every three to four years. In the intervening years, ratoon crops would be grown from the regrowth from the plant rootstock remaining following harvesting.

Sugarcane harvesting operations would be similar to methods used in ORIA Stage 1. All cane-harvesting operations would take place during the dry season (April to November), and would be scheduled to provide a continuous supply of cane to the raw-sugar mill.

Sugarcane harvesting would involve burning of the crop immediately prior to harvest. Burning is considered necessary to reduce the amount of trash associated with the cane at harvest, and it is also considered beneficial in the control of pests.

As is common practice throughout Australia, farm owners would be responsible for the day-to-day management of farm operations. However, certain constraints to management practices would apply to farms within the Project Area. These would include the timing of the harvest to maintain mill throughput, and the honouring of environmental commitments made in this ERMP/draft EIS and any environmental conditions that may apply to the Project.

On-farm water management

All farms in the Project Area would be developed with irrigation tailwater management systems. Irrigation tailwater is the water leaving the end of the furrows during watering and is unavoidable if uniform water application to the crop is desired. The tailwater management system proposed for use in the Project Area would consist of tailwater ditches, tailwater dams, and tailwater return pumps and pipelines that would return irrigation tailwater to the farm irrigation system for application to the crop.

Rainfall runoff from the cropped areas would also be collected by the tailwater collection system. The tailwater storage dams have been designed to act as first-flush collection systems for stormwater. First-flush stormwater is likely to contain higher concentrations of organic matter, fertiliser and other farm chemicals than stormwater arising later in the rainfall event or from subsequent rainfall events.

The first-flush stormwater would be retained in the tailwater management system for subsequent use as irrigation water. The remainder would discharge to the drainage infrastructure, which in turn would drain to the Keep River or to Sandy Creek.

Farm chemicals and their use

The predominant crop grown on the Project Area would be sugarcane. Experience with this crop in ORIA Stage 1 has shown that it has a low requirement for pesticides. The primary means of managing diseases in sugarcane is to plant with varieties known to be naturally resistant to such diseases.

The likely fertiliser requirements for sugarcane grown in the Project Area, based on experience in ORIA

Stage 1, are urea and diammonium phosphate. Weed control would also be required, and this would be provided by a combination of mechanical tillage of the soil and application of pre-emergent and post-emergent herbicides.

Farm chemical and fertiliser requirements for crops other than sugarcane would be similar to the range of agricultural chemicals currently used in ORIA Stage 1. Also in accordance with current practice in ORIA

Stage 1, application of farm fertilisers and chemicals would involve direct application of fertiliser to the seed bed and tractor-drawn boom-spraying and aerial-spraying in the case of herbicides and pesticides. Management regimes of chemical and fertiliser use, in terms of type, timing and method of application, would be incorporated into the Environmental Management Plan (EMP) to be developed for the Project Area.

Irrigation, drainage and flood protection infrastructure

The Water Corporation would be responsible for providing the off-farm irrigation, drainage and flood protection infrastructure required by the Project.

The proposed M2 Channel and other smaller supply channels would be open excavations with sloping sides. Compacted clay channel-lining would be provided where channel excavation is required to be constructed in more permeable soils. This lining would be at least half a metre thick over the bed and the lower 1 to 2 metres of the channel batters.

Three balancing storage dams are proposed to facilitate operation of the irrigation supply system, particularly in meeting peak demand or in providing buffer storage at times other than normal operating conditions. These balancing storage dams would consist of a clay-lined perimeter embankment with an internal lining of stone riprap to prevent erosion from wave action. They would also include entry and exit structures with remote controlled gates.

The control system for the irrigation infrastructure would be based upon a modern remote control system designed to maximise efficiency of water distribution while minimising operating costs.

The drainage system for the Project would comprise a variety of open, excavated drains that would convey stormwater runoff from developed farm areas to natural drainage features. These open drains would be located along low points in such a way that they service each farm unit.

Hillside drains would be provided at the perimeters of developed farmland to divert stormwater runoff from adjacent catchments. These structures would be embankments less than 3 metres in height, combined with limited excavation to ensure continuous longitudinal drainage.

Farmland adjacent to significant waterways would be protected from flooding by levees. Flood protection levees would be earth embankments generally 1 to 3 metres in height, with 2:1 side slopes and a 4 metre crest width.

Sugar-milling

The proposed raw-sugar mill has been sized to have a crushing capacity of about 750 tonnes of cane per hour, enabling an annual sugarcane crush of approximately 3.2 million tonnes.

Sugarcane delivered to the mill would be weighed, shredded and then fed to a crushing mill to maximise juice extraction.

Processing of the juice would involve heating, clarification and concentration of the sugar by evaporation of water in the presence of a slurry of seed crystals. After a period of crystal growth, the molasses would be separated from the raw-sugar crystals by centrifuging, and recycled for further recovery of sugar. The raw-sugar crystals would then be dried and stored in bins. The syrup from which it is uneconomic to extract further sugar (molasses) would also be stored in bins.

Cane fibre ('bagasse') from the crushing mill would be burnt in the boiler as fuel for the generation of steam. Ash from the boiler, comprising the unburned residue of bagasse, would be spread over the canefield to act as a soil conditioner and fertiliser.

Atmospheric emissions from the raw-sugar mill would consist of water vapour from the process equipment and the normal products of combustion from the bagasse and fuel-oil-fired boiler. Prior to any atmospheric discharge, the emissions would be passed through an emission cleaning system to ensure compliance with all relevant regulations.

Liquid discharges from the mill would predominantly consist of cooling water and relatively small quantities of process effluent that would be treated in a biological treatment plant, combining activated sludge and anaerobic processes. The treated effluent may be used as irrigation water on the canefields adjacent to the mill.

Materials handling and transport

Transport of cane would be carried out using purpose-designed road transport vehicles with a payload of approximately 100 tonnes. For the long-term sugarcane supply to the mill of 3.2 million tonnes per annum, approximately eight trucks would arrive at the mill every hour over a 24-hour period, seven days a week for seven months of the year.

Raw-sugar and molasses transport from the mill to the port of Wyndham would be carried out over the processing season in purpose-built road transport vehicles with a payload of up to 90 tonnes. Approximately thirty vehicle movements per day are anticipated for product transport from the Project Area. Transport from the Project Area to Wyndham would be via the existing Kununurra-Wyndham road.

The main product storage facilities would be developed adjacent to the Wyndham wharf, with a nominal capacity of 180,000 tonnes for raw sugar and 75,000 tonnes for molasses. Development of these storage facilities would require the reclamation of a portion of an unvegetated mud flat adjacent to the southern section of the Wyndham wharf access road.

Shipment sizes from the port of Wyndham are currently constrained to approximately 20,000 tonnes. On this basis, at full production, twenty-eight shipments would be required annually, meaning that shipments would leave Wyndham on average every thirteen days.

4 PHYSICAL ENVIRONMENT

The climate of the Project Area is typical of the Kimberley region, with two dominant seasons - a wet and a dry. The wet (monsoon or cyclone) season usually extends from November to April, while the dry season occurs from May to October.

The average annual rainfall at Kununurra is 776 millimetres, with around 90% falling during the wet season. Net evaporation rates are high, approximately 2,000 millimetres per annum. During most months, evaporation exceeds precipitation.

The area that would be developed for farmland is confined to three fluvial plains: the Weaber Plain, the Keep River Plain and the Knox Creek Plain. The Weaber and Knox Creek plains form wide and generally flat valleys at an elevation of approximately 25

metres Australian Height Datum (AHD). The Keep River Plain, located adjacent to the lower reaches of the Keep River, has an elevation varying from about 20 metres AHD in the south-west to about 10 metres AHD in the north-west.

Soil surveys indicate that cracking clay soils, known as Cununurra and Aquitaine clays, are dominant within the Project Area. Cracking clay soils are often described as black soils or vertisols. They exhibit significant shrinking and swelling properties which result in deep, open desiccation cracks during the dry season.

The landforms within the Project Area would be modified from the existing primarily natural state of flat, open grasslands and savanna, to a highly managed agricultural landscape. The drainage patterns of the plains would be modified to provide a more consistent gradient and to facilitate optimum water application and farm drainage. In addition, a formal drainage system would be developed within and around the Project Area.

Despite thirty years of irrigated agriculture, ORIA Stage 1 has neither salinity problems nor problems associated with sodic soils (sodicity). However, if not managed appropriately, the cracking clay soils may be susceptible to sodicity as a result of the bicarbonate present in the irrigation water. Sodicity issues would be managed in the Project Area through focused management of irrigation practices. Numerical modelling has shown that the irrigation practices proposed for the Project would result in an average leaching rate to groundwater of about 100 millimetres per annum. The data available from ORIA Stage 1 indicate that this leaching rate would be sufficient to avoid adverse levels of subsoil sodicity.

Long-term monitoring would be undertaken to ascertain any changes to surface and subsoil salinity and sodicity resulting from the proposed irrigation practices. Alternative management measures would be investigated and trialled if the monitoring were to detect subsoil sodicity levels sufficient to threaten the long-term sustainability of irrigated agriculture within the Project Area.

5 SURFACE WATER

As with ORIA Stage 1, releases of water from Lake Argyle, flowing via the Ord River and Lake Kununurra, would be the source of irrigation water for the Project Area. However, unlike ORIA Stage 1, the entire Project Area would be contained within the lower reaches of the Keep River and Sandy Creek catchments; therefore, no drainage flows from the Project Area would re-enter the Ord River.

The Water and Rivers Commission is the authority in Western Australia responsible for managing the allocation of water resources so that water is used efficiently within sustainable limits and to ensure that the needs of people, industry and the environment are balanced. The Water and Rivers Commission recently prepared a Draft Interim Water Allocation Plan for the Ord River for public comment and review by the EPA.

In the Draft Interim Water Allocation Plan, the Water and Rivers Commission noted that an allocation of 1,235 gigalitres per annum from the Ord System for irrigation purposes was sustainable (1 gigalitre equals

1 million cubic metres). The Water and Rivers Commission has proposed that the allocation for irrigation purposes would allow sufficient water for other uses, such as hydropower and mining activities, as well as for necessary environmental flows. The water allocated for all uses, including adequate environmental flows, approximates the net annual inflow into the Ord River Dam (net annual inflow equals inflow from streams and rainfall less evaporation losses).

The allocation to irrigation includes the projected water requirements of ORIA Stage 1 and ORIA Stage 2, including the Project Area. The estimated water consumption for irrigation purposes in the Project Area is consistent with the irrigation allocation in the Draft Interim Water Allocation Plan.

The hydrology of the lower reaches of the Keep River would be affected by containment of flood waters within flood protection levees and by land and drainage modification within the Project Area. That is to say, that the natural flooding over wide areas of the adjacent plains, which currently occurs during the wet season, would be curtailed in certain locations by the proposed flood protection levees. Hydrology models were used to optimise the proposed location of the flood protection levees with respect to minimisation of increases in peak flood levels and velocity.

Through the design process, it is considered possible to contain the predicted flood levels to a naturally occurring range, although peak flood levels at the higher end of the range may occur more frequently.

In regard to water velocity, the hydrology models predict minor or no increases in peak average flow velocity at most locations. One exception is in the lower reaches of Border Creek; however, erosion problems are not anticipated to result due to the rocky nature of the substrate at this location.

The provision of formalised drainage infrastructure would alter the rainfall runoff characteristics from the Project Area. If the proposed development were to proceed, there would be a net increase in the average flow in the lower reaches of the Keep River. This increase would be within the natural variability of surface-water flows due to the variable nature of rainfall in the region.

The capture and reuse of tailwater within the farms are expected to virtually eliminate discharges (arising from normal irrigation operations) from farming areas to surrounding natural drainage features during the dry season. This is consistent with the existing natural conditions where negligible surface runoff occurs during the dry season.

The water management measures for the proposed development would represent an application of current best-practice techniques in the ORIA. An analysis of the potential for elevated nutrient levels in receiving waters as a result of the proposed development was completed by comparing nutrient levels in drains from ORIA Stage 1 with recorded nutrient levels in the Keep River. The comparison indicated a low potential for environmental impact as concentrations of nutrients in ORIA Stage 1 drains are similar to natural levels of nutrients in the Keep River.

The majority of the Project Area would be devoted to the cultivation of sugarcane. Sugarcane has a relatively low requirement for pesticides, and no requirement for endosulfan. It is anticipated that the low requirement for pesticides, coupled with the

proposed water management measures, would mitigate any environmental impact on the receiving aquatic environment.

At this stage, the types of crops to be grown on the land made available to independent farmers is unknown. As a consequence, a precautionary approach is to be adopted with respect to the use of pesticides in the Project Area. For example, interim restrictions would be imposed on any use of endosulfan in the Project Area. The interim restrictions would require any application of endosulfan to receive prior approval from the Environmental Management Entity (EME) that would be established in conjunction with the Project. The interim restrictions would include monitoring of farm drains, tailwater return systems and drainage flows to confirm the effectiveness of the proposed management measures.

6 GROUNDWATER

The groundwater environment beneath the Project Area is considered currently to be in equilibrium, with groundwater levels reflecting a balance between geological formation and recharge from the surface. Development of the Project Area for broad-acre flood irrigation would change the hydrological cycles on the land and result in a change in the rate of groundwater recharge and, hence, a change in groundwater levels. These changes are expected to result in an increased rate of water infiltration (known as accessions) to underlying aquifers and a consequent rise in groundwater levels.

Management of accessions to groundwater

Accessions to groundwater could be expected from the irrigation infrastructure and the irrigated farmland. Best-practice standards, in both the construction and the operational phases of the Project, would be implemented to manage accessions to groundwater.

The proposed methods for management of accessions to groundwater from the proposed irrigation infrastructure are as follows:

- Irrigation channels would be constructed with clay lining so that the rate of infiltration would be less than 2 millimetres per day.
- Balancing storage dams would be sited in areas where the dominant surface soils are of Aquitaine clay. (Aquitaine clay is the least permeable soil type occurring in the Project Area.)
- Drainage channels would be designed to be broad and shallow to take advantage of the naturally occurring soil conditions; these consist of lower permeability clays nearer the surface, overlying soils of increasing permeability with depth.

The proposed management measures represent current best-practice construction standards for irrigation infrastructure. In addition, modern quality assurance procedures would be adopted during construction to ensure that the design intent is achieved in practice.

Sugarcane has a relatively high irrigation water requirement. Nearly all of this demand is needed to offset crop evapotranspiration, and irrigation schedules developed to satisfy

this requirement only would eliminate accessions to groundwater. However, there are a number of reasons why it is neither practical nor desirable to eliminate all accessions to groundwater. For example, some accessions to groundwater would be required to remove salts from the root zone of the crop that would otherwise accumulate from the consistent application of irrigation water, even for the low-salinity water sourced from Lake Kununurra. Also, some leaching of water through the soil profile would be desirable as a means of managing potential sodicity effects within the soils of the Project Area.

The proposed groundwater management strategy would involve the direct control of groundwater levels by the long-term use of dewatering bores and, to a lesser extent, field drains.

Dewatering bores would extract groundwater from the permeable palaeochannels that underlie much of the Project Area. The optimal locations for the dewatering bores would be determined following further field investigations. Current planning assumes that the dewatering bores would be uniformly spread over areas underlain by palaeochannels or other permeable strata, with minor variations in location made to accommodate infrastructure and farm unit boundaries.

In less permeable areas, it is considered likely that field drains would be more effective than dewatering bores. Field drains would consist of a series of perforated pipes laid below the surface and would allow the entry and collection of groundwater.

The results of the groundwater modelling undertaken for the Project indicate that dewatering bores and field drains would only need to be operated after ten years of cropping; even after that time their installation could be phased in over a number of years. Any collected groundwater would be variable in time both in terms of quantity and quality, with the latter initially being highly dependent upon existing groundwater quality.

Collected groundwater would initially be utilised as irrigation water, following dilution in the irrigation channels with water sourced from Lake Kununurra.

In some areas the quality and quantity of the extracted groundwater would be such as would allow this practice to occur in the long term. However, project planning is currently based upon the conservative assumption that, in the long term, all extracted groundwater would be collected by a network of buried pipelines for subsequent discharge to the estuarine (tidal) sections of the Keep River and Sandy Creek.

Black soils have been observed in other irrigation areas in Australia as being effective in preventing the migration of pesticides from the surface to groundwater. Also, black soils typical of the Project Area are known to be highly effective in binding phosphorus, a key element of fertilisers. Hence, significantly elevated levels of phosphorous are not anticipated in the groundwaters beneath the Project Area.

The migration of nitrogen to groundwater is known to be less affected by soil conditions. The predicted groundwater nitrate levels in the Project Area would be about twice the naturally occurring levels, yet the level is still sufficiently low as not to restrict any future beneficial uses of the groundwater.

Existing environment - terrestrial vegetation and flora

The Project Area lies within the Victoria-Bonaparte Biogeographic Region, which adjoins the lower part of the Joseph Bonaparte Gulf and is about 73,000 square kilometres in extent. This biogeographic region exhibits a diversity of landforms and vegetation types, including red earth and black-soil (cracking clay) plains, plateaux, ranges of sandstone, open savanna and tall grassland.

European occupation of the Kimberley region has historically been sparse and, as a consequence, biological studies have been relatively limited. Detailed vegetation and flora surveys within the Project Area have recently been conducted in relation to the proposed development. Prior to these comprehensive surveys, no detailed flora surveys had been conducted on the black-soil plains within the Project Area.

The following discussion summarises the terrestrial flora currently existing within the Project Area. A comprehensive conservation strategy is proposed for the Project Area, which would be implemented if the proposed development were to proceed. A summary of the strategy is outlined in Section 10.

Vegetation in and adjacent to the Project Area

The Western Australian portion of the Project Area was described by Beard (1979) as 'grassland with sparse bauhinia (*Bauhinia cunninghamii*) and coolibah (*Eucalyptus microtheca*) on cracking clay soil'. In 1990 Beard further expanded the description of the black-soil plains of the Ivanhoe Land System, describing it as treeless, or with low trees 3-6 metres high, including *Eucalyptus microtheca* (coolibah), *Bauhinia cunninghamii* (bauhinia), *Acacia suberosa* (corky bark wattle), *Terminalia* spp. and *Excoecaria parvifolia* (guttapercha tree). Shrubs include *Acacia farnesiana* (mimosa bush) and sparse *Carissa lanceolata* (conkerberry). The typical ground layer is a community of tall, perennial grasses reaching 2 metres and more in height. Common grass species include *Dichanthium tenuicolum* (blue grass), *Dichanthium fecundum*, *Sorghum plumosum* (plume sorghum), *Sorghum timorense*, *Eulalia fulva* (silky browntop), *Ophiuros exaltatus* (canegrass) and *Astrebula squarrosa* (bull mitchell grass).

The portion of the Project Area within the Northern Territory, mapped by Wilson et al. (1990), consists largely of *Chrysopogon fallax* (golden beard grass) and *Dichanthium fecundum* (blue grass) grassland.

Compared with other black-soil plains in the Victoria-Bonaparte Biogeographic Region at Auvergne Station, the Project Area has a predominance of *Sorghum timorense*, *Acacia* cf. *bidwillii* and *Themeda triandra*, and a scarcity of *Sorghum bulbosum*. The Project Area also has a greater diversity and possibly

a higher biomass of plant species than the Auvergne region, but the same dominant species are present in each region.

Based on information from field surveys, a total of seventy-two vegetation communities within seventeen major groups has been recognised within the Project Area.

The major vegetation associations of particular conservation significance within the region are vine thickets and rainforest (Beard 1990). Rainforest was not recorded within the Project Area. An area along the middle reaches of the Keep River was recorded as a vine thicket, but was considered degraded due to the long history of pastoral activity.

Flora of the Project Area

Data provided by the Western Australian Herbarium and the Parks and Wildlife Commission of the Northern Territory show that 307 taxa of plants from eighty families were previously recorded within the Ord River area. The most numerous families are Poaceae (grasses), Myrtaceae (eucalypts and paperbarks), Cyperaceae (sedges and rushes), Mimosaceae (wattles), Asteraceae (daisies), Papilionaceae (peas) and Combretaceae (*Terminalia* spp.).

The field surveys of the Project Area recorded 682 taxa from eighty-seven families, twenty-six of which were represented by a single taxon. Two hundred and seventy-six genera were recorded, with 138 of these represented by a single taxon. The number of plant taxa recorded for the Project Area was doubled by the field surveys.

Western Australia and the Northern Territory have different requirements for the conservation of flora. Within Western Australia, rare plant species are protected by the Wildlife Conservation Act 1950. The Act is administered by the Department of Conservation and Land Management (CALM) and prohibits the taking of any Declared Rare Flora on any lands anywhere in Western Australia without the written consent of the Minister for the Environment. CALM also maintains a supplementary listing of rare flora species referred to as 'Priority Flora'.

Rare flora in the Northern Territory is protected by the Parks and Wildlife Act 1993. This Act includes a schedule of protected plants (and animals) and a supplementary list of flora species.

Sixteen taxa known to occur within the Project Area have been listed by either the Western Australian or the Northern Territory Governments as threatened, rare or poorly known. An additional three taxa are listed by the Northern Territory as restricted in Central Australia but common throughout the remainder of the Territory. Fourteen taxa considered to be rare within the Northern Territory were recorded within the Northern Territory portion of the Project Area, two of which are classed as Priority Flora in Western Australia. Four taxa of priority status were recorded in Western Australia: two were considered to be restricted to Western Australia and two were threatened in the Northern Territory.

Of the rare and priority species of conservation significance recorded in the Project Area, fourteen species are not exclusive to the Kimberley region, and occur in other regions of Western Australia, the Northern Territory and Queensland, with some also occurring in tropical Africa and Asia.

Introduced flora

Eighteen introduced plants were recorded in the Project Area. Seven of the introduced plants have been declared noxious weeds under the Agriculture and Related Resources

Act 1976, in Western Australia, and the Northern Territory Noxious Weeds Act 1978, in the Northern Territory. None of the noxious weeds are listed in the National Weeds Strategy (Agriculture and Resource Management Council of Australia and New Zealand et. al. 1999).

The black cracking clay soil areas of the Project Area have not been significantly affected by weed invasion.

8 EXISTING ENVIRONMENT – TERRESTRIAL FAUNA

The Project Area falls within the Torresian Zoogeographic Region, which encompasses the humid tropical and subtropical areas of northern Australia. This region incorporates the Kimberley region of Western Australia, much of the 'Top End' of the Northern Territory, and northern Queensland.

Most of the fauna encountered within the Project Area is adapted to the wet-dry tropical environment and has Torresian distributions. However, the distribution of some species is more wide-ranging, and some have strong affinities with the Eyrean Biogeographic Region (semi-arid to arid areas). Other fauna, in particular birds, may be even more wide-ranging, with distributions throughout Australia or overseas; these include trans-equatorial migratory species.

The following discussion summarises the terrestrial fauna currently found within the Project Area. Proposed conservation initiatives in relation to terrestrial fauna are outlined in Section 10.

Fauna habitats of the Project Area

Fauna habitats are closely aligned with landforms and associated vegetation. Seven fauna habitats have been recognised in the Project Area. Three of these habitats are widespread and broadly categorised as savanna woodland (grassland, eucalypt woodland and Bauhinia woodland), while the remaining four (riverine woodland, vine thicket, wetland and rock outcrops) are more restricted and provide more specialised habitats.

The majority of habitats encountered in the Project Area are savanna woodland, which occurs on the black-soil or red-soil plains. Three subtypes may be distinguished: the grassland habitat is typically found on soils inundated in the wet season and subject to cracking in the dry season; eucalypt woodland is a grassland with a few shrubs and emergent trees, dominated by *Eucalyptus* spp. and *Corymbia* spp.; and Bauhinia woodland is a grassland with a few shrubs and emergent trees, dominated by *Bauhinia cunninghamii*.

The riverine woodland adjoining the Project Area is a localised but relatively important habitat, with an abundance and diversity of species. It occurs along the margins of the Keep River, Knox Creek, Sandy Creek and on the levees adjacent to them, and is subject to inundation during the wet season.

Vine thickets occur in small localised patches within the riparian areas of the Keep River in the Project Area, and consist of a variety of tree and vine species.

Wetlands in and adjacent to the Project Area include billabongs, permanently inundated areas, and artificial water storage areas (e.g. dams and tanks). These areas provide a diverse array of ecological niches which support a range of vertebrate and invertebrate fauna species.

Several rock outcrops occur throughout the Project Area. Rock crevices, loose rocks and small caves provide numerous niches for specialist saxicoline (rock-inhabiting) fauna species. Rock crevices may be utilised by geckos, while caves may be used as roosts for bats, or as shelter for a range of fauna.

Vertebrate fauna

Literature searches indicate that the Project Area may support as many as 240 bird, fifty-five native and eight introduced mammal, 102 reptile and twenty-seven frog species.

Based on all surveys of the Project Area, nine mammal families have been recorded, comprising twenty-eight native mammal species; these are Dasyuridae (carnivorous marsupials - three species), Macropodidae (kangaroos and wallabies - four species), Pteropidae (fruit bats - two species), Vespertilionidae (true bats - nine species), Megadermatidae (ghost bats - one species), Hipposideridae (horseshoe bats - two species), Emballonuridae (sheath-tail bats - two species), Molossidae (freetail bats - one species) and Muridae (rats and mice - four species).

The total number of bird species recorded for the Project Area is 166. During the dry season when water is scarce, the wetland and riverine woodland habitats provide valuable refuges for birds. This is reflected by the highest levels of species richness being recorded in these areas (sixty-three and forty-one species respectively). By contrast, the grassland offers few dry-season habitats and consequently had the lowest species richness.

During the wet season the widespread abundance of water allows for the dispersal of many bird species. During this period, structurally diverse habitats (vine thicket, eucalypt woodland and rock outcrop) have recorded the highest species richness (thirty-five, twenty-nine and twenty-eight bird species respectively). Grassland habitat has recorded the lowest species richness (fifteen bird species), presumably due to the limited number of ecological niches available in this habitat.

The total number of reptile species recorded to date for the Project Area is forty-five while the total number of frog species recorded to date is twenty.

Groundwater and cave fauna

Stygofauna are fauna (usually invertebrate) that exclusively live in subterranean habitats, principally caves. One species of stygofauna has been found in the palaeochannels of the Project Area as well as in groundwater of ORIA Stage 1.

Bats also commonly inhabit caves, especially during breeding and daylight hours. A total of seventeen species of bats has been recorded from the Project Area, of which five species frequent caves and other rock outcrops. However, bats forage over extensive

ranges, and any caves or dense vegetation in the vicinity of the Project Area could be utilised by bats.

Rare and protected fauna

Seventeen vertebrate species considered rare and protected under Commonwealth and State legislation could be expected within the Project Area. These include one mammal, eleven birds, two reptiles and three frogs, including the previously presumed extinct frog species, flat-headed frog, which was recently found at Cockatoo Lagoon in the Keep River National Park.

Two species recorded in the Project Area are listed under the Commonwealth Endangered Species Protection Act 1992: Derby white-browed robin (*Poecilodryas superciliosa*) is classified as endangered, and ghost bat (*Macroderma gigas*) is classified as vulnerable.

Black bittern (*Ixobrychus flavicollis gouldi*) is listed as Schedule 1 species under the Western Australian Wildlife Conservation Act 1950. An additional four species recorded within the Project Area are listed under Schedule 4 of the Act: peregrine falcon (*Falco peregrinus*), radjah shelduck (*Tadorna radja*), freshwater crocodile (*Crocodylus johnstoni*) and saltwater crocodile (*Crocodylus porosus*).

Ghost bat (*Macroderma gigas*), zitting cisticola (*Cisticola juncidis*) and wailing frog (*Cyclorana vagitus*) are listed under Schedule 7 in the Northern Territory.

Flat-headed frog (*Limnodynastes depressus*) is classed as a critically vulnerable species in the Northern Territory. Two recently described lizard subspecies - *Ctenotus rimicola rimicola* and *Ctenotus rimicola campestris* - were rated by the taxonomists Horner and Fisher (1998) as 'rare or insufficiently known' in both Western Australia and the Northern Territory.

An additional thirteen species of birds listed under the China-Australia Migratory Bird Agreement (CAMBA) were recorded in the Project Area.

Introduced species

Three introduced species - naturalised dingo (*Canis lupus dingo*), cat (*Felis catus*) and donkey (*Equus asinus*) - were recorded in the Project Area. Native rat (*Rattus villisissimus*) is present in the Project Area and occasionally reaches plague proportions in ORIA

Stage 1. Introduced rodents, such as house mouse (*Mus musculus*) and black rat (*Rattus rattus*), are expected to occur within the Project Area. Other mammals expected to occur are horse (*Equus caballus*) and feral pig (*Sus scrofa*). Cattle (*Bos indicus*) are widespread across the Project Area due to pastoral activities.

Existing environment aquatic flora and fauna

The proposed conservation strategy for the Project would ensure that all rivers, streams and natural wetlands in the Project Area are contained within conservation areas, and are isolated from land development.

Throughout the Project Area the vegetation fringing the creeks, rivers and other watercourses is dominated by *Barringtonia acutangula* (freshwater mangrove), *Melaleuca*

argentea (paperbark), *Pandanus spiralis* (screw palm), *Carthormium umbellatum*, *Acacia colei* (wattle) and *Eucalyptus* species, including *Eucalyptus camaldulensis* and *Excoecaria parvifolia* (guttapercha tree). These species are mainly associated with fresh or slightly brackish water. Scattered mangroves occur along the northern reaches of the Keep River within the Project Area; however, extensive mangrove woodlands exist nearby in the estuarine portion of the Keep River, and outside the Project Area.

Aquatic vegetation and flora

The records of the Western Australian Herbarium were used to determine which aquatic species were likely to occur in the Project Area. In addition, during the fauna study of the Keep River by Larson (1999), opportunistic recordings of aquatic plants were made.

Larson (1999) recorded the aquatic vegetation in the pools along the Keep River near the southern boundary of the Project Area as comprising:

- mixed grasses, Nardoo (*Marsilea* sp.) and algae *Chara* spp. and *Enteromorpha* spp. in the water;;
- spikerush (*Eleocharis* spp.) and taro (*Colocasia esculenta*) in the soil at the water edge.

At Alligator Hole and Milligan Lagoon, Larson (1999) recorded *Nymphaea macrosperma* and *Nymphaea violacea* (waterlilies), *Nymphoides indica*, *Najas tenuifolia* (water nymph), *Utricularia australis* (bladderwort), *Hydrilla verticillata* (water thyme) and *Chara* spp.

No rare or priority flora was recorded from the aquatic environment.

Aquatic fauna

A survey of aquatic fauna in and near the Project Area was undertaken in October 1998 (Larson 1999). Seventeen sites were sampled along the Keep River and Sandy Creek.

The survey recorded five mammal, ninety-three bird, thirteen reptile, eleven frog and thirty-five fish species. The survey results showed that the aquatic invertebrates comprise assemblages typical of Northern Territory rivers, creeks and billabongs. Insects and molluscs were found to be common in most waterbodies and some insects were locally common.

No feral fish were recorded. Two species of sawfish have been recorded in the Keep River - dwarf sawfish (*Pristis clavata*) and freshwater sawfish (*Pristis microdon*). Dwarf sawfish is coastal in distribution but can travel long distances up rivers into fresh water. Its conservation status is unknown but it may only occur in northern Australia. Freshwater sawfish is listed as 'vulnerable' under the Commonwealth Endangered Species Act 1992. Freshwater sawfish is usually found in fresh water and in the upper reaches of estuaries, and may be isolated in small billabongs for several years until floodwaters enable it to return to the estuary. Freshwater sawfish has been recorded from several rivers in Western Australia, the Northern Territory and at Cape York in Queensland.

Introduced flora and feral fauna

No introduced species of plants and animals were recorded from the aquatic environment.

10 BIOLOGICAL ENVIRONMENT – IMPACT MANAGEMENT

A comprehensive conservation strategy has been proposed as an integral feature of the development of the Project Area. It is the view of Wesfarmers-Marubeni and the Water Corporation that the proposed strategy conforms with commitments made in relation to conservation by the Commonwealth, State and Territory Governments. A key element of the strategy is the establishment of some 40,000 hectares of conservation reserve within the Project Area. This would include representative areas of the vegetation associations, faunal habitats and major soil types found in the Project Area. Furthermore, an EME would be formed to implement the conservation strategy and the strategy would be formalised in an EMP.

Existing and proposed reserves in the Victoria-Bonaparte Biogeographic Region

The Victoria-Bonaparte Biogeographic Region has a total area of 72,970 square kilometres, approximately 73% of which is in the Northern Territory and 27% in Western Australia. The area set aside in conservation reserves in the Northern Territory is 6,846 square kilometres (approximately 13%); in Western Australia, the area in conservation reserves is 2,443 square kilometres (also approximately 13%). The conservation reserves in Western Australia include Lake Argyle and Lake Kununurra. Each lake was formed as a result of the ORIA development and each has since become listed under the Ramsar Convention as valuable habitat for aquatic birds, including migratory birds.

As signatories to the National Strategy for the Conservation of Australia's Biological Diversity, the Western Australian, Northern Territory and Commonwealth Governments are committed to the establishment of a comprehensive and representative system of ecologically viable protected areas. Following development, the Project Area would include undeveloped areas that would be managed for conservation. These proposed conservation areas would provide an important contribution to the national conservation estate.

The Governments of Western Australia and the Northern Territory continually review their systems of conservation reserves. The proposed development would provide significant opportunities for the State and Territory Governments to increase conservation areas, particularly as these initiatives could be completed in parallel with the excision of the Project Area from existing pastoral leases. For example, the Northern Territory Government is considering a significant expansion of the Keep River National Park which may increase the conserved area in the Victoria-Bonaparte Biogeographic Region by approximately 220,000 hectares.

Conservation within the Project Area

The key environmental and conservation management objective in relation to the proposed development is the management of a world-class broad-scale agricultural development, with integral conservation areas, in accordance with Australia's environmentally sustainable development and biodiversity policies. Conservation management would take into account issues such as indigenous habitats and species, traditional land uses, community involvement, water and land pollution, construction and operational activities, and pest species.

The objectives of conservation management would be to:

- minimise environmental disturbance consistent with development requirements;
- maintain and not degrade the biological integrity and diversity in the Project Area and adjacent regions/areas;
- manage conservation areas to the satisfaction of the community and government agencies.

The priorities for environmental management of the Project Area are to:

- protect scheduled and other significant species, including those protected under international agreements;
- preserve site or habitat-specific areas;
- sustain biological diversity in terms of species richness criteria;
- conserve genetic resources;
- control erosion.

These priorities have been considered in the context of representation of scheduled species and suitable habitats in conservation reserves in the East Kimberley and the adjacent parts of the Northern Territory.

A key element of the conservation strategy is the retention of representative associations and habitats of the Project Area within distinct conservation areas. For example, all rock outcrops and watercourses, including wetlands and billabongs with environmental and cultural significance, would be conserved. To maintain the effectiveness of these areas as fauna habitats, a system of corridors would provide links to adjacent areas of the surrounding Cockatoo Land System.

All the major soil types that occur in the Project Area would be represented within the conservation areas, although some of the minor soil types represented in small areas would not be protected. Farm development would focus on the cracking clay black-soil areas comprising Cununurra and Aquitaine clays. A minimum of 24% and 15% respectively of these soils would be conserved in the Project Area.

All undeveloped land within the Project Area would be managed for conservation. Most of this conservation area would be located around the perimeter of the Project Area, thereby providing an important physical link with undeveloped areas. In the Northern Territory this would include the proposed extension of the Keep River National Park and, in Western Australia, the Point Spring Nature Reserve.

Four of the seventy-two recognised vegetation associations would not be conserved to some extent in the Project Area. However, the combined extent of these associations is 133 hectares and represents only 0.4% of the proposed development area. Twelve vegetation associations only occur in the proposed conservation area and therefore would not be affected by development. Of the remaining fifty-six vegetation associations only one would not have at least 10% represented in the conservation area.

Two currently unreserved or poorly reserved vegetation associations in the Victoria-Bonaparte Biogeographic Region in the Northern Territory - *Melaleuca minutifolia* low woodland and *Xerochloa* grasslands - would be included in the proposed conservation areas. The conservation of these two vegetation associations within the Project Area would significantly increase the size and comprehensiveness of their conserved area within the biogeographic region.

The only association of restricted distribution in the Project Area is an *Echinochloa kimmerleyensis* dominated swamp near the foothills of the Weaber Range. This swamp would be included within the proposed conservation area and would be protected.

No threatened communities covered by the Endangered Species Protection Act 1992 occur in the Project Area.

All the identified fauna habitats would be represented in the proposed conservation areas within the Project Area. All rare species of, and specially protected, fauna identified with the Project Area would have their usual habitat retained.

Assessment of potential impacts

The proposed development would take place predominantly on the black-soil plains. These cracking clays are typically dominated by savanna woodland, a homogeneous habitat consisting of *Bauhinia* woodland, eucalypt woodland and grassland. Habitats associated with black soils are widespread in the Kimberley and the Northern Territory.

Mammals

As with any sizeable land development, it is inevitable that individuals of some of the smaller species of mammals may be detrimentally affected during construction activities. Some may move, and survive, within the proposed conservation areas. Other individuals may be displaced and may later succumb to predators, stress or territorial conflicts during attempts to re-establish a home range. However, none would become locally extinct.

Clearing of the black-soil vegetation would reduce the foraging habitat for some terrestrial (arboreal) species and some bats, as well as remove some den and roost trees. However, the areas of natural vegetation preserved on the hills and along watercourses within the proposed conservation areas would minimise this particular impact.

Birds

Nesting sites and foraging areas for birds may unavoidably be impacted during construction activities, but it is envisaged that most individuals would be able to move into the adjoining proposed conservation areas. In ORIA Stage 1, some birds - including brolgas, magpie geese, radjah shelduck, parrots and finches - have benefited from the development of irrigated farms.

Reptiles

Some individuals may relocate to adjoining proposed conservation areas, but some may unavoidably be killed during construction activities. Based on existing information for

ORIA Stage 1, most of the reptile species would not be adversely affected and it is considered likely that some may benefit from the establishment of the irrigation system.

Frogs

It is anticipated that most, if not all, species of frogs would continue to live and possibly thrive in the irrigated areas. Those with specialist habitat niches - such as Copland's rock frog, which is restricted to the rock outcrops - would probably not be affected by the proposed development.

Fish and aquatic biota

The proposed conservation areas would include all significant waterways, billabongs and wetlands, and their associated riparian vegetation. Direct impacts upon the habitats of fish and other aquatic biota would therefore be avoided, except in two localised areas associated with the road crossings of the Keep River and Knox Creek.

The predicted changes to the hydrology of the Keep River and Sandy Creek from proposed development are not expected to result in any significant impacts on fish and other aquatic biota in these two watercourses. The altered flow regime may cause some localised erosion, but this should stabilise with time. The differential effect of the increased average flows would be greater in drier years and, at these times, the additional flows that would occur earlier and later in the wet season would benefit an environment that would otherwise be under stress.

Stygofauna

The predicted changes to the groundwater environment of the Project Area would include a rise in groundwater levels; therefore, existing habitats would remain flooded. Only minor changes to groundwater quality arising from the use of farm chemicals are predicted.

No significant changes to groundwater quality arising from the use of farm chemicals are predicted to occur.

Taking the above predictions into account, it would appear that the potential for impact on the stygofauna of the Project Area is very low. The continued presence of stygofauna in groundwater beneath ORIA Stage 1, which has been used for irrigated agriculture for over thirty years, would support this conclusion.

Existing conservation reserves

The Keep River National Park is approximately

6 kilometres south of the Project Area. Being upstream of the Project Area, it is unlikely that the Keep River National Park would suffer any significant direct detrimental impact as a result of the proposed development.

Point Spring Nature Reserve, less than a kilometre north of the Weaber Plain portion of the Project Area, protects a permanent spring, remnant rainforest and a small wetland at

the base of the Weaber Range. The Point Spring Nature Reserve is a Class A reserve for the conservation of flora and fauna. This reserve includes small areas of black soil and sandy alluvium. Point Spring is in a separate groundwater system to the adjacent alluvial plains and, as a consequence, would be isolated from any changes in the water table in the Project Area. However, its close proximity to the Project Area has necessitated the implementation of special management and design considerations, with particular reference to anticipated higher flood water levels and flow velocities. A buffer zone has been incorporated into the design of the proposed development to insulate Point Spring Nature Reserve from these effects.

All other conservation reserves in the region would be sufficiently removed from the Project Area so as not to be affected by the Project.

Environmental management

An EMP would be prepared prior to development to guide planners and mitigate any potential environmental impact associated with the proposed development. The EMP, which would be made available for public comment prior to finalisation, would consider both construction and operation activities.

The EME that would be established in conjunction with the proposed development would be responsible for ensuring implementation of the EMP.

There is potential for the Miriwung and Gajerrong people to be involved in the development of the EMP and operations of the EME. Wesfarmers-Marubeni and the Water Corporation consider that the management of the biodiversity issue would be enhanced by the input of Miriwung and Gajerrong people.

Permanent monitoring sites for flora, fauna and biodiversity would be established in conservation areas, along ecological corridors and in selected sites in the Project Area. Monitoring would be undertaken on a regular basis with the monitoring parameters clearly defined following consultation with the staff of CALM and the Parks and Wildlife Commission of the Northern Territory.

To limit any potential for overclearing, all areas designated for construction works would be clearly marked on development maps, and on the ground prior to commencement of works. Vegetation clearance would also be staged so that areas would be cleared only as required.

All contractors and consultants would be required to participate in a formal environmental and cultural heritage induction programme on the importance of the natural and social environment.

Advice would be sought from CALM and the Parks and Wildlife Commission of the Northern Territory in the preparation of a Fire Management Plan for the Project Area, including the proposed conservation areas. This plan would take into account community assets, environmental values, fire frequency and season, and the impact that fire could have on human life.

Various mechanisms would be used to control the introduction of weeds to the Project Area. Mandatory interstate quarantine would be maintained to control weeds from other

areas. During construction, all construction machinery would be cleaned of soil and other organic debris prior to being transported to and from the Project Area.

Once construction and development works are complete, each farmer would be responsible for the recognition and control of weeds on their property.

The EME would oversee the environmental management of the Project Area, including the identification of weeds in the Project Area, and provision of advice and assistance about control/eradication.

A strategy for public access through the conservation areas would be developed. Areas in and around the Project Area are currently utilised for recreational and, in the case of Miriung and Gajerrong people, cultural purposes; however, with improved access, the incidence of human impact could increase as a result of the proposed development. Signage about the Project Area and surrounds, and defined roads or tracks to the more popular areas, should assist with management. At popular areas (e.g. Keep River) camping grounds complete with composting toilets would need to be established.

Rehabilitation of any sites disturbed during the proposed development would be undertaken progressively. Areas disturbed during development of the infrastructure would be rehabilitated as each stage of the work is completed, particularly those drainage channels designated as conservation-vegetation corridors.

Where possible, topsoil would be utilised immediately or removed and stockpiled for later use on disturbed areas. Once the development was complete, the topsoil would be spread over the disturbed areas, allowing seeds and root stock stored in the soil to germinate and become established. Active reseedling of some areas would also take place.

A seed collection programme would be undertaken before vegetation is cleared. A seed mix appropriate to the area to be rehabilitated would be prepared and scattered over the disturbed areas. Alternatively, seedlings could be germinated and planted out at the commencement of the wet season. Only seeds of plant species endemic to the Project Area would be used in revegetation projects.

11 LAND USE

Grazing of cattle for beef production is a major local industry and more than half of the Kununurra-Wyndham area is used for pastoral activities. The Project Area has been utilised for pastoral activities for approximately one hundred years. Pastoral leases associated with Ivanhoe Station in Western Australia, and Legune and Spirit Hills stations in the Northern Territory, cover most of the Project Area.

Leasehold improvements made in the Project Area include fencing, holding yards, gates, groundwater bores, tanks, small dams and aircraft landing strips.

A number of rubbish dumps also exist and some areas have been quarried to provide road construction materials.

A limited amount of mining exploration occurs in the region. In the recent past, exploration for alluvial diamonds was conducted in the west Ivanhoe area. Deposits of lead, zinc and silver are known to exist at Sorby Hills, north-east of the Pincombe Range, but as yet the deposit has not proved sufficiently attractive for commercial development. The Weaber Gas Field, situated at the southern end of the Keep River Plain, is not commercially exploited at the present time.

A Kununurra-Wyndham Area Development Strategy is being developed by the Ministry for Planning and the Kimberley Development Commission with assistance from the Shire of Wyndham-East Kimberley and the Department of Lands, Planning and Environment. The aim of the strategy is to assess the regional planning implications arising from potential future development of the Project Area and other regional developments.

Land tenure within the Project Area

The Project Area is impacted by native title and land rights claims in Western Australia and the Northern Territory. The approach taken by Wesfarmers-Marubeni and the Water Corporation with respect to native title and land rights issues in the Project Area is for resolution of land issues by way of a negotiated settlement with Miriuwung and Gajerrong people.

The preferred land tenure for the various portions of the Project Area would vary depending upon the intended use. Wesfarmers-Marubeni would seek freehold title on land proposed for farms, the sugar mill, and the construction camp. The Water Corporation would seek freehold title on land to be developed for the purposes of irrigation infrastructure. It is envisaged that land required for public roads, communication sites and associated infrastructure would be special-purpose reserves vested in Government.

A feature of the proposed development would be the establishment of conservation areas within the farmed area, and around the perimeter of the farmed area. These conservation areas would be established to ensure that significant habitats and cultural heritage sites are protected and maintained. The proposed conservation areas would be managed by the EME.

It is envisaged that access to the portion of the Keep River within the proposed conservation area would remain open, and designated recreation sites for fishing and picnicking purposes would be established. Access to the remainder of the proposed conservation area may be restricted, where considered appropriate, to control erosion and weeds as well as to protect the regeneration of the flora and fauna habitats.

Land-use impacts and mitigation measures

Pastoral activities would be inconsistent with the proposed broad-acre agriculture, and displacement and severance of pastoral activities would be an unavoidable consequence of the Project proceeding. Pastoral activities within the Project Area would progressively be scaled down; however, the areas involved would be relatively small in comparison

with the existing pastoral leases. The boundary of the Project Area would be fenced, where appropriate, to prevent ingress of cattle.

Development of roads would lead to improved access between Kununurra and the Project Area. However, it is recognised that road development may also have perceived negative impacts resulting from an increase in human impact in and around the Project Area. Project development would include road signage to limit human movement where considered appropriate.

Northern Australia has become an increasingly popular holiday destination for Australian and international tourists because of the region's scenic beauty, unique landforms, and relaxed and distinctively Australian lifestyle. Tourism is to some extent a seasonal industry, with an estimated 60% of tourists arriving between April and November when temperatures are relatively low. It is likely that regional tourism and recreation area usage will continue to increase whether or not the Project proceeds. However, it is anticipated that improved infrastructure and services such as roads and accommodation that would result from the proposed development would lead to increased tourist numbers and to longer sojourns.

12 ISSUES SPECIFIC TO MIRIUWUNG AND GAJERRONG PEOPLE

The land encompassing the Ord and Keep rivers, including the Project Area, is of traditional and current significance to Miriuwung and Gajerrong people.

Historical overview

The introduction of the pastoral industry in the East Kimberley resulted in a diminished opportunity for Aboriginal people to maintain their traditional lifestyle. Many Aboriginal people worked on the pastoral stations and were still able to practise their traditional lifestyle, conduct ceremonies, hunt and to visit country on weekends and during the wet season. However, the advent of equal wages for Aboriginal people in 1969 in the pastoral industry dramatically decreased Aboriginal employment. This in turn resulted in the relocation of Aboriginal people from the pastoral stations into towns such as Wyndham and the newly established Kununurra.

The early development of the ORIA Scheme occurred at a time when there was no legal requirement to formally consult with, or consider, Aboriginal issues. In recent years, Aboriginal people have actively sought to have their traditional rights recognised, to participate in the economic development process, and to share in the benefits of economic development.

Consultation with Miriuwung and Gajerrong people

Consultation with Miriuwung and Gajerrong people in relation to the potential ORIA Stage 2 developments began in 1995.

The Western Australian Government undertook consultations with Miriuwung and Gajerrong people from 1995 to 1998. Since 1998, Wesfarmers-Marubeni and the Water Corporation have taken over the lead role in consultation with respect to the Project Area, after being awarded an exclusive mandate in April 1998 to investigate the viability of the development of the Project Area.

Wesfarmers-Marubeni and the Water Corporation recognise the need to establish a working relationship with the Aboriginal community. Extensive consultation is ongoing with Miriuwung and Gajerrong people, as well as with the Aboriginal representative bodies - the Aboriginal Legal Service, the Kimberley Land Council and the Northern Land Council.

Wesfarmers-Marubeni and the Water Corporation have established a community relations team of three staff to facilitate ongoing communication with Miriuwung and Gajerrong people in relation to the proposed development. Two members of the team reside permanently in Kununurra.

Native title and land claims

Miriuwung and Gajerrong people lodged three native title claims over a significant portion of the East Kimberley in Western Australia and the Northern Territory, in 1994 and 1995. The claims cover the entire Project Area.

Unlike Western Australia, the Northern Territory has an additional legislative procedure by which Aboriginal people can claim land - the Aboriginal Land Rights (Northern Territory) Act 1976 (ALRA). In 1997, the Legune Area Land Claim was lodged on behalf of Miriuwung and Gajerrong people, and this claim affects the portion of the Project Area within the Spirit Hills Pastoral Lease.

In 1998, the Federal Court of Australia determined that Miriuwung and Gajerrong people hold native title rights to an area of land the subject of the first of the three native title claims. The determination area covers approximately 7,900 square kilometres and includes the Ord River, Lake Argyle and approximately 100 square kilometres of the Project Area.

For land which is the subject of a native title determination or land which is the subject of a native title claim, the native title holders and claimants may voluntarily surrender their native title rights and interests by way of a negotiated settlement. Such a negotiated settlement is known as an Indigenous Land Use Agreement (ILUA). Typically, parties to an ILUA can include Aboriginal native title holders and claimants, Aboriginal representative bodies, project proponents and Governments. Mutually agreed benefits packages for the native title holders and claimants are a key element of any ILUA, in return for the voluntary surrender of native title rights and interests over the land, thereby enabling development to occur.

The proposed development could not occur until all native title issues over the Project Area are resolved. The preferred approach of Wesfarmers-Marubeni and the Water Corporation is to resolve all native title issues in relation to the Project Area by concluding an ILUA with Miriuwung and Gajerrong people. Resolution of the native title issues by way of an ILUA is considered to be the most equitable way of securing access to land in the Project Area, and the most pragmatic approach to a timely resolution of the issues.

Cultural heritage

Miriuwung and Gajerrong people have strong social and cultural links to each other and to their traditional land.

There have been a number of cultural heritage assessments undertaken in the broader region both by independent consultants and by Government officers. However, to date, there has been no comprehensive ethnographic or archaeological assessment of the Western Australian portion of the Project Area, encompassing the Weaber and the Knox Creek plains. There has, however, been a comprehensive ethnographic assessment (sacred site survey) of the Northern Territory portion of the proposed farmland by the Aboriginal Areas Protection Authority. Also, a comprehensive archaeological assessment has been undertaken of the same land by the Department of Lands, Planning and Environment.

Cultural heritage sites are protected by State, Territory and Commonwealth legislation. Wesfarmers-Marubeni and the Water Corporation are committed to ensuring compliance with relevant State, Territory and Commonwealth heritage legislation, as well as to meeting the expectations of Miriuwung and Gajerrong people in respect to the protection of cultural heritage.

In 1998 and 1999, Wesfarmers-Marubeni and the Water Corporation formally consulted the relevant Western Australian, Northern Territory and Commonwealth Government departments with respect to the location, spatial dimensions and significance of known cultural heritage sites within the Project Area. The available information on cultural heritage sites provided by the various Government agencies was overlaid on topographic plans of the Project Area.

The proposed project design, including the farmland, the irrigation channels, drains and roads as well as the potential sugar mill sites, was superimposed on the plans to ascertain whether any known cultural heritage sites would be affected by the initial design. This exercise revealed that five ethnographic sites may potentially be affected, and the proposed design was modified to ensure that these sites would not be disturbed.

A predictive model has indicated that land units classified as having moderate archaeological sensitivity could be expected on 4% of the land. Land units classified as having high to very high archaeological sensitivity could be expected on 4% of the land; however, this land would not be developed for agricultural purposes. The remaining 92% of the land could be expected to be of low archaeological significance and would be unlikely to contain significant archaeological sites. The predictive model was validated during the archaeological assessment undertaken within the Project Area in October 1998.

Due to time constraints, a single cultural heritage assessment of the entire Project Area was not completed in the 1998 dry season. However, time permitted the completion of an assessment of cultural heritage issues with respect to a programme of investigatory geotechnical works. The assessment was co-ordinated by the Kimberley Land Council and the Northern Land Council, and was completed on:

- a 50 metre wide corridor approximately 400 kilometres length within which proposed irrigation channels, drains, levees and roads would be located;
- six potential sugar mill sites.

As a result of the assessment, the proposed alignment of the M2 Channel adjacent to Cave Springs has been re-designed, and four of the original six potential sugar mill sites have been discarded from further consideration.

A further cultural heritage assessment would be required within and around the Project Area prior to the commencement of the proposed development.

It is proposed that the findings of the cultural heritage assessments would support the development of a Cultural Heritage Management Plan, which would define how the cultural heritage values within the Project Area would be protected and managed for the life of the Project.

Aboriginal social impact

Over the last twenty-five years there have been a number of studies into the social and economic impact on Aboriginal people in the East Kimberley region as a result of pastoral, agricultural and mining development. Significant studies completed to date have been commissioned by the Kimberley Land Council and the State and Commonwealth Governments.

Research has found that Aboriginal people in the region had experienced a series of significant changes in the 1960s and early 1970s. These changes have included the introduction of equal wages, the increased reliance on capital intensive investment in the pastoral industry, and the establishment of ORIA Stage 1. All the changes have led to some dislocation of Aboriginal communities and consequent social disruption.

The Kimberley Land Council has noted potential economic opportunities for Aboriginal people in relation to the proposed development. In July 1998, over 300 people attended a conference, co-ordinated by the Kimberley Land Council, entitled 'The Kimberley - Our Place, Our Future'. In the conference proceedings, it was stated that 'major opportunities in the region include the expansion of tourism, the full development of the Ord River irrigation area, the expansion of pearling, and the development of a capacity to process meat'.

Wesfarmers-Marubeni and the Water Corporation are to address Aboriginal social impact issues through the completion of an Aboriginal Socio-Economic Impact Assessment (ASEIA) in relation to the Project. Completion of an ASEIA is not a legal requirement for Wesfarmers-Marubeni and the Water Corporation; however, it is considered likely that completion of an ASEIA would provide a valuable insight into the social and economic expectations, and any concerns, held by Miriuwung and Gajerrong people in relation to the proposed development. As a consequence, it is likely that completion of an ASEIA would assist all parties in the negotiation and settlement of an ILUA.

The aim of the ASEIA is to provide sufficient information about the proposed development to Miriuwung and Gajerrong people to enable them to identify and assess

any potential resultant impact. The objective of the ASEIA is to ensure that any potential impact from the proposed development is assessed with respect to:

- a Miriuwung and Gajerrong understanding of country, the use of land and access to culturally important areas and landscapes in and around the proposed development;
- any impact on the ability of Miriuwung and Gajerrong people to live in accordance with their own values, traditions and aspirations;
- any impact on community structures and vitality, and economic vitality;
- historical and current responses to previous developments in the region;
- the preferred outcomes of Miriuwung and Gajerrong people regarding the proposed development;
- the maximisation of potential positive impacts and the mitigation of any potential negative impacts.

13 AIR QUALITY AND NOISE

Dust

It is inevitable that dust would be generated during construction, predominantly from the earthworks associated with the development of farm blocks, service roads, irrigation channels and drains.

The impact of dust on the local community from construction activities would be mitigated by the remoteness of the Project Area from existing residences. An exception relates to the proximity of a section of the proposed M2 Channel, which in some areas is within 300 metres of permanent residences. These residences are located south of the M2 Channel alignment and, therefore, would be predominantly upwind of the construction activity.

Smoke and ash

Existing growers in ORIA Stage 1 have adopted cane-burning prior to harvest, and this practice is considered the preferred method for the Project. Occasional complaints associated with smoke and cane ash fallout have been lodged with local Government regulatory agencies. Changing production practices to green-cane harvesting (which does not involve cane-burning prior to harvest) in ORIA Stage 1 has been investigated in the past and not adopted for a variety of reasons, including the subsequent difficulties that may be experienced in relation to flood irrigation of the crop.

The remoteness of the Project Area from existing communities - some 30 kilometres north-east of Kununurra - would mitigate any potential effects arising from cane-burning.

The sugar mill would primarily be powered by energy from the burning of bagasse in a boiler. Emissions to the atmosphere would consist of the normal products of combustion

from the boiler chimney and the water vapour from cooling towers and steam safety valves.

It is envisaged that the boiler would be operated continuously during the crop harvesting season.

Prior to discharge from the boiler chimney the gases would be passed through a scrubber to ensure that particulate levels conform with relevant emissions guidelines.

Greenhouse gas emissions

It is estimated that the proposed development would result in a net decrease in Australian greenhouse gas emissions. The reduction, whilst not significant on a global scale, would be consistent with commitments made by the Commonwealth Government under the Kyoto Protocol in 1997.

Project development would entail removal of approximately 35,000 hectares of the existing vegetation cover of grass and sparse trees, and replacement of much of that area with agricultural farmland. The principal crop would be sugarcane, a perennial grass that would be grown on most of the farm area. The amount of carbon stored in the Project Area in both the existing and the proposed scenarios would vary seasonally. However, it is estimated that the minimum carbon stored would increase following development, from about 19,500 tonnes to about 670,000 tonnes at full development. Most of the increase would be from the growth of sugarcane during the dry season following progressive harvesting of the crop. The estimate includes the effects of burning of the sugarcane prior to harvest, and includes the carbon content in the raw sugar and molasses that would be in storage at the end of the dry season.

It is estimated that the proposed development would result in a net reduction of the level of carbon dioxide (a greenhouse gas) in the atmosphere, through the storage of carbon dioxide as carbon within the sugarcane once the Project has reached full production. The estimates indicate that the magnitude of the reduction on an ongoing basis would be approximately 160,000 tonnes per annum of carbon dioxide equivalent carbon.

Noise

The Project Area is currently typical of isolated rural areas with respect to a general absence of development and low ambient noise levels.

Noise would be generated during construction from large earth-moving machinery associated with earthworks, land-clearing and levelling. Noise would also be generated at construction sites (e.g. at the sugar mill) and from general vehicle movements. The main noise-generating activity of the Project, such as noise created at the sugar mill and as part of farming and transportation operations, would occur at distances of 30-80 kilometres from Kununurra and, under these circumstances, would have negligible effect on existing residences.

Construction work associated with the proposed M2 Channel may at times be within 300 metres of existing residences. Management measures, such as controlling the hours of

construction activities, would be adopted to mitigate any potential adverse impacts on these residences.

14 PUBLIC HEALTH

Mosquito-borne diseases

The flavivirus that causes Murray Valley or Australian encephalitis, and the alphavirus that causes Ross River fever, are the two most important pathogenic arboviruses causing human disease in Australia. The mosquito *Culex annulirostris* is an important vector in the transmission of both the Murray Valley encephalitis and the Ross River virus. *Culex annulirostris* breeds in fresh water and is the predominant species of mosquito found in the Ord River area.

Australian encephalitis is potentially fatal. The Murray Valley encephalitis virus is recognised as the main aetiological agent of Australian encephalitis, although a few cases are caused by the closely related Kunjin virus.

The disease caused by Ross River virus is much more common than Australian encephalitis. Although, it is debilitating, it is fortunately not fatal to its victims. However, the symptoms can persist for many months or even years. Ross River virus is one of the most frequently isolated arboviruses in Australia and has been obtained from more than thirty species of mosquito in six genera. Recently, the north-east Kimberley region was identified as having the highest case attack rate of Ross River virus in Australia.

Since 1972 the Arbovirus Surveillance Laboratory at the University of Western Australia has been monitoring mosquito populations in the Kimberley region. In 1981 the first sentinel chicken surveillance flock was established and by 1989 the number of flocks had increased to twenty-four throughout the Kimberley, Pilbara and Gascoyne regions. Similar sentinel programmes were established in 1992 in the Northern Territory. These programmes have shown that Murray Valley encephalitis virus is enzootic (always present) in several areas of the Kimberley, particularly in the Ord River area.

Management action would be taken in conjunction with the proposed development to reduce the risk of increased infection with arboviruses. These actions would concentrate upon the following activities:

- designing and operating the Project so as to reduce the potential for increased mosquito-breeding activity;
- designing education programmes for the Project's construction and operational workforce on measures that could be taken to reduce their personal risk of infection;
- extending the existing monitoring programmes to cover the Project Area.

Farm chemicals in the environment

Development of land for farming purposes is generally associated with an increased use of agricultural chemicals. In some instances the use of farm chemicals has led to conflicts with adjacent land users, particularly if there have been any concerns regarding possible health effects on the surrounding community from exposure to the chemicals.

The public health issues associated with the use of agricultural chemicals in the Project Area would be mitigated by the absence of other intensive land uses nearby and by the dominance of sugarcane cultivation, which has minimal chemical requirements for successful growth. However, management measures are proposed in relation to the issue of farm chemicals and the environment.

Commonwealth, Territory and State Governments, and industry regulations in relation to the handling and use of agricultural chemicals would be implemented throughout the Project Area to reduce any risk to public health. Management measures to minimise potential health impacts outside the Project Area would focus on reducing chemical use and controlling the main transport mechanisms.

Wherever possible, any application of chemicals within the Project Area would be from tractor-drawn boom-sprays. The proposed technology would result in relatively large spray droplets being released close to the ground in order to minimise potential for spray drift. For any aerial-spraying, only operators who have successfully undertaken the pilot accreditation programme of the Aerial Agricultural Association of Australia would be utilised, and the timing and manner of application would be carefully chosen to minimise spray drift.

The risk of transporting chemicals from the Project Area in surface water to adjacent areas would be minimised through the on-farm water management systems. Similarly, the low chemical requirements for sugarcane cultivation, combined with the prevalence of heavy soils which are known to impede the transport of chemicals through the soil, suggest that contamination of groundwater in the Project Area by agricultural chemicals is unlikely. Nonetheless, as an additional precaution, groundwater supplies would be monitored on a regular basis for all chemicals used in the Project Area to ensure compliance with relevant criteria.

15 COMMUNITY ISSUES

Existing social environment

The nearest population centres to the Project Area are the towns of Kununurra (approximately 30 kilometres south-west of the easternmost extremity of the Project Area) and Wyndham (approximately 100 kilometres west of Kununurra). Both towns are in the Shire of Wyndham-East Kimberley, within the Kimberley region of Western Australia. The nearest population centres in the Northern Territory are the settlement of Timber Creek and the town of Katherine, respectively around 220 kilometres and 510 kilometres east of Kununurra.

In 1996, the Kimberley region had an estimated population of around 25,000, which is approximately 1.5% of Western Australia's population. Three-quarters of the Kimberley population reside in urban centres. The remaining one-quarter is spread throughout twenty relatively large and sixty smaller Aboriginal communities, 100 pastoral stations, seven mining sites and in the farm area of ORIA Stage 1.

About one-quarter of the Aboriginal population of Western Australia lives in the Kimberley region, and Aboriginal people comprise about 34% of the total population of the Shire of Wyndham-East Kimberley.

The Aboriginal and non-Aboriginal populations display very different demographic and settlement trends.

The Aboriginal population is demographically stable, relatively young (40% under fifteen years of age), and has a well-balanced gender ratio. By comparison the non-Aboriginal population is more transient, is 56% male, and has a higher representation of persons aged between twenty-five and fifty-four years.

A comparison of socio-economic indicators shows that, in 1996, Kununurra was more affluent than the Kimberley as a whole, and that Kununurra had a lower unemployment rate than the Western Australian average.

Existing regional economy

The dominant industries in the Kimberley region are mining, aquaculture and fishing, tourism, irrigated agriculture and pastoralism. Whilst mining dominates in terms of gross domestic value, the fly-in/fly-out component of some of the operations has limited the regional economic flow-on effect.

The pastoral industry and irrigated agricultural operations are the two major activities contributing to agricultural production in the region. Irrigated agricultural production has increased significantly in recent years; it is based predominantly on horticultural and broad-acre crops grown in the ORIA near Kununurra and also includes smaller agricultural holdings near Broome and Derby. The pastoral industry is based on rangeland production of beef cattle, which are predominately exported live from the region.

Tourism has become a major industry in the Kimberley with the region's scenic beauty and unique landforms being important drawcards for tourists.

Workforce and population projections

The estimated direct workforce required for the proposed development would be approximately 550 full-time equivalent positions. This estimate includes employment on the corporate and independent farms, in the sugar mill, in harvest and transport operations, in water supply operations, in environmental management, and in management and administration.

Project planning is based upon an estimated indirect workforce of seventy-five people and an induced workforce of 200. Indirect employment refers to jobs in businesses supplying goods and services to the agriculture sector. Induced employment refers to

jobs created by the personal consumption and associated activities of people employed directly and indirectly in the agriculture sector.

It is anticipated that the numbers of construction personnel would range from 250 to 650 per annum over a three-year period. Whilst many construction workers would be sourced locally, it is anticipated that the majority would originate from outside the Kimberley region and would be accommodated in a self-contained construction camp in the centre of the Project Area.

The construction camp would initially be developed to accommodate approximately 650 construction workers at any one time, all with 'single' status. At the completion of construction, the construction camp may be reconfigured, to yield in approximately 200 single accommodation units that could be used by seasonal workers during the operational phase of the Project.

The estimates of net population increase in Kununurra range from 1,397 persons to 1,954 persons. The range in the estimate results from some uncertainty regarding the anticipated level of employment of people currently living in Kununurra but who are currently unemployed.

Social impact assessment

The Kununurra-Wyndham Area Development Strategy (KWADS) is in the final stages of preparation by the Ministry for Planning and the Kimberley Development Commission. KWADS is intended to provide direction for the long-term use and management of land in the Kununurra-Wyndham area. It will also promote further co-ordination of activities and initiatives of community, private enterprise and Government agencies with responsibilities in the area.

Of importance to the Project is that the KWADS is to consider the land-use planning and infrastructure needs of the Kununurra-Wyndham area in the context of further development of ORIA Stage 2, including the proposed development of the Project Area. KWADS should provide a sound basis for statutory authorities to plan the long-term provision of services in the area, including any significant expansion of Kununurra.

There may be a need for between 500 and 700 new dwellings to be constructed as a result of the proposed development. The 200 single units that may remain operational in the construction camp following the end of project construction activities may meet part of this requirement. It is envisaged that the remainder of the Project's accommodation requirements would be serviced by the township of Kununurra. Sufficient residential lots in the undeveloped portion of the existing Lakeside subdivision and the proposed Hidden Valley subdivision are available for the building of over 600 additional houses and flats, which would be sufficient to meet the accommodation requirements associated with the proposed development.

The central hospital facility in the East Kimberley is the Kununurra Hospital, which has twenty-six beds and an existing average demand of around twenty-two beds. The influence of the proposed development and other ORIA Stage 2 developments has been factored into the planning requirements of the Kununurra Hospital. Plans exist to add

another ten beds to the hospital to accommodate any increase in demand for hospital services from anticipated growth.

It is likely that the East Kimberley Aboriginal Medical Service may be required to service a larger patient load due to a significant increase in the non-Aboriginal population in Kununurra. Currently, more than 30% of the patients using the service are non-Aboriginal. Increased resource allocations or changed policies on access to the clinic in Kununurra may be required to maintain the current level of provision of medical services to Aboriginal patients.

Kununurra has two schools: Kununurra District High School (pre-primary to Year 12) and St Joseph's Catholic Primary School, which mainly caters for Aboriginal students of pre-primary and primary age. Currently there is no senior high school in either Kununurra or Wyndham. The anticipated population growth and projected increase in enrolments may necessitate development of another combined pre-school and primary school. The population growth may also precipitate an upgrade of the Kununurra District High School to a senior high school, an initiative that would be welcomed by the local community.

Given the importance of the local waterways for both recreational and lifestyle purposes, the maintenance of access to the waterways is an important social impact issue. This is particularly true for the local Aboriginal community for whom access to the riverbanks and the water is of socio-cultural importance. The Project has been designed in such a way that access to the Keep River would be maintained. The proposed development would have no impact on access to the Ord River.

As the majority of construction personnel would be accommodated in a construction camp at the centre of the Project Area, the social impact of this workforce on the people and facilities of Kununurra is expected to be minimal. A high standard of amenities would be provided at the construction camp, including recreation and entertainment facilities, thereby limiting the need for construction workers to travel to Kununurra on a daily basis. However, it is likely that during the construction phase, additional custom would be generated for local businesses.

Community consultation

Significant community consultation has been undertaken in relation to the proposed development.

Community consultation relating to the Project commenced in 1996 on behalf of the Department of Resources Development and continued in 1998-99, during preparation of the ERMP/draft EIS. These consultation activities have included the use of a range of media outlets, brochures, public displays and meetings, and direct consultations.

A resident community relations team was established by Wesfarmers-Marubeni and the Water Corporation in Kununurra in mid-1998. The role of the team is to keep the local community informed on issues arising from the development of the Project on a regular basis. This team is supported by regular visits by other staff of Wesfarmers-Marubeni and the Water Corporation and their consultants.

Consultation with local Aboriginal people has been extensive during 1998-99 and is ongoing. This consultation has been facilitated by the community relations team, and has included regular presentations given to the local community.

Environmental management framework

The need for an environmental management framework

The proposed development has a number of distinctive characteristics relevant to ongoing environmental management. These include:

- a Project Area that is relatively large and would include related but discrete activities such as the supply of irrigation water, farming and processing;
- a farmed area which would be predominantly developed and operated by Wesfarmers-Marubeni in the initial phase but perhaps sold down in part or whole to independent farmers in the future;
- a Project Area that straddles the border between Western Australia and the Northern Territory, which may induce cross border issues with respect to environmental compliance legislation;
- the legal recognition of Miriuwung and Gajerrong native title rights over a portion of the Project Area and the existence of native title claims over the balance of the Project Area;
- high community expectations with regard to environmental management.

To address these characteristics Wesfarmers-Marubeni and the Water Corporation consider it appropriate that an environmental management framework should be developed for utilisation throughout the construction and operational phases of the proposed development. Key elements of such a framework should:

- be structured to suit the proposed development and be site specific;
- clearly and transparently articulate environmental responsibilities and accountability;
- accommodate the need for ongoing environmental monitoring and reporting;
- be appropriately resourced over the long term.

Relevant legislative issues

As the Project Area straddles the border between Western Australia and the Northern Territory, the proposed development would be subject to a range of State and Territory legislation. Similarities and differences currently exist with respect to relevant State and Territory legislation applicable to the proposed development. For example, the portion of the proposed development within Western Australia would currently be subject to the Environmental Protection Act 1986, and the portion within the Territory would be subject to the Environmental Assessment Act 1994. Whilst the effect of each Act is substantially similar, differences exist which could give rise to complications during the development and operational phases of the Project.

To address any potential complications which may arise from legislative issues, the State and Territory Governments have undertaken to form a Ministerial Council. The Ministerial Council is to comprise a Minister from each of the State and Territory Governments, and would oversee the recommendation and adoption of appropriate legislation to be applicable over the Project Area.

The development of an environmental management framework

To assist in the conceptual development of an environmental management framework for the Project Area, a review of environmental frameworks currently being implemented in a number of irrigation areas throughout Australia has been completed. It was noted that most of the environmental management frameworks currently operational in Australia have been developed to 'retrofit' existing operations. Furthermore, the industry being retrofitted was often characterised by a relatively large number of participants, ranging from small-scale operators to government agencies. As a consequence, and to balance existing and often competing interests, the environmental frameworks were relatively complex and involved significant government intervention.

In contrast to many existing irrigation schemes, the proposed development is to be characterised by the involvement of three large and reputable organisations - Wesfarmers, Marubeni and the Water Corporation - rather than a relatively large number of small-scale operators. This factor has been taken into consideration in the development of a conceptual framework for environmental management, in addition to the analysis of existing environmental frameworks in operation in Australia, and the distinctive characteristics of the proposed development.

It is the view of Wesfarmers-Marubeni and the Water Corporation that the nature of the proposed development, including the proposed industry structure, and the perceived key elements of an effective environmental management framework lend themselves to industry self-management.

Outline of the proposed environmental management framework

The proposed development would comprise three core industry activities:

- the development and operation of irrigated farmland, predominantly for the purpose of growing sugarcane;
- the development and operation of a raw-sugar mill;
- the development and operation of irrigation and drainage infrastructure.

It is envisaged that any environmental conditions laid down by the Minister for the Environment would be assigned to the owners of the respective key assets, and it would follow that each of the asset owners would have environmental responsibilities and obligations under the relevant environmental management.

Due to the interrelated nature of the core industry activities, Wesfarmers-Marubeni and the Water Corporation propose that an entity be established to shoulder the operational aspects of ongoing environmental management in relation to the proposed development on behalf of the industry participants.

The proposed entity, or EME, would be owned by the industry participants, and would provide environmental management services to the owners. Key features of the proposed EME would be as follows:

- The EME would be wholly owned by the industry participants, including all three core industry participants.
- The key objective of the EME would be the management of environmental issues within the entire Project Area, on behalf of the industry participants.
- The EME would be responsible for aspects such as ongoing monitoring, analysis, and reporting on behalf of industry within the proposed development - but legal responsibility for environmental compliance would rest with the individual asset owners.
- The EME would be the focal point for community input in relation to environmental issues in relation to the proposed development.
- The EME would be resourced by the industry participants within the proposed development.

An important aspect of the environmental management framework is the implication, if any, of future transfer of asset ownership. It is envisaged responsibility for legal and statutory environmental compliance would rest with the relevant individual asset owners. Assignment of an interest in any asset, in part or whole, would involve the transfer of legal or statutory environmental compliance responsibility to the new owner. It is also planned that shareholder rights and obligations with respect to the EME would be assigned to the asset, and flow with any asset transfer.

Table of Environmental Factors Relevant to the Project

Factor	Site Specific Factor	WA EPA objective	Existing Environment	Potential Impact	Environmental management	Predicted Outcome
Biophysical						
Biodiversity	Ecosystems	To maintain biological diversity meaning the different plants and animals and the ecosystems they form, at the levels of genetic diversity. Species diversity and ecosystem diversity	The Project is located within the Victoria–Bonaparte Biogeographic Region. This biogeographic region extends over 72,972 km² and includes land in the Northern Territory and Western Australia. Approximately 13% of this biogeographic region are currently in conservation reserves. The Project Area would extend over 75,760 hectares of land currently used for pastoral purposes, and include approximately 34,800 hectares that would be developed for irrigated agriculture and infrastructure, and 40,960 hectares that would be managed for conservation. The proposed development would take place predominately on the black-soil plains. These cracking clays are typically dominated by savanna woodland, a homogenous habitat consisting of <i>Bauhinia</i> woodland, eucalypt woodland and grassland. Habitats associated with black soils are widespread in the Kimberley and the Northern Territory. The Project Area would also include riparian vegetation and habitats (riverine woodland and vine thicket) associated with watercourses, billabongs and wetlands, and large areas of rock outcrops. Habitats associated with riparian areas and rock outcrops are also widespread in the Kimberley and the Northern Territory.	Clearing of approximately 34,800 hectares of vegetation predominantly associated with cracking clays of the black soil plains within the Project Area. The remainder of the Project Area would be managed for conservation. The ERMP/EIS identifies the opportunities for land adjacent to the Project Area, currently used for pastoral purposes, to be added to the conservation estate by Government as a consequence of the Project proceeding.	The project development plan contains features to mitigate the consequences of vegetation clearing and to ensure maintenance of biodiversity in the region. These features include: - the provision of dedicated conservation areas within the Project Area; - the maintenance of riparian vegetation along watercourses and permanent waterbodies, including provision of buffer zones between these and development areas. - the provision of corridors for the movement of fauna, between areas set aside for conservation and the surrounding undeveloped country. - the provision of a buffer zone nominally 1,500 m wide around the farm areas. - the active management of all conservation areas, buffer zones and, wherever possible, infrastructure corridors for the purpose of conservation. As a minimum, management of the areas would include removal of stock, control of access, monitoring and control for weeds and introduced species, and monitoring of environmental and ecological parameters.	The proposed conservation areas contain vegetation assemblages that are representative of those found in the Project Area, as well as flora and fauna identified as having regional conservation significance. Black soil plains, the predominant soil type targeted for development, would have approximately 25% of its extent in the Project Area retained and managed for conservation. The EPA’s objectives can be met by conserving and managing viable ecosystems <i>in-situ</i>. Implementation of opportunities to add to the conservation estate would significantly enhance the maintenance of biodiversity within the Victoria–Bonaparte Biogeographic Region.
Terrestrial flora	Vegetation communities	Maintain the species diversity, geographic distribution and productivity of vegetation communities.	A total of seventy-two vegetation communities within seventeen major groups are recognised for the Project Area. The Keep River Plain has extensive areas of grassland with no, or only a few, scattered trees, which include <i>Eucalyptus microtheca</i>, <i>Corymbia bella</i>, <i>Excoecaria parvifolia</i>, <i>Acacia ditricha</i> and <i>Bauhinia cunninghamii</i>. The vegetation of the Knox Creek Plain is predominantly grassland with emergent to dense low trees dominated by <i>Eucalyptus microtheca</i>, <i>Excoecaria parvifolia</i>, <i>Atalaya hemiglauc</i>a and <i>Bauhinia cunninghamii</i>. The Weaber Plain is a grassland with emergent trees dominated by <i>Eucalyptus microtheca</i>, <i>Excoecaria parvifolia</i> and <i>Terminalia obovata</i> subsp. <i>volucris</i>. Sections of the Weaber Plain retain water for longer periods and have grassland species associated with wetter areas (e.g. <i>Oryza australiensis</i> and <i>Ophiurus exaltatus</i>). The only association of restricted distribution in the Project Area is a <i>Echinochloa kimberleyensis</i> dominated swamp near the foothills of the Weaber Range. No threatened communities covered by the <i>Endangered Species Protection Act</i> 1992 occur in the area. Two currently unreserved or poorly reserved vegetation associations in the Victoria–Bonaparte Biogeographic Region in the Northern Territory—<i>melaleuca minutifolia</i> low woodland and <i>Xerochloa</i> grasslands occur in the Project Area.	The proposed development would require clearing of approximately 34,800 hectares of predominately black-soil plains. These cracking clays are typically dominated by savanna woodland, a homogenous habitat consisting of <i>Bauhinia</i> woodland, eucalypt woodland and grassland. Approximately 40,960 hectares of land within the Project Area, comprising black soil plains and all of the riparian areas and rock outcrops would be managed for conservation. Grazing pressure from stock would be removed from the conservation areas. These areas would also be monitored and managed for weeds. The <i>Echinochloa kimberleyensis</i> dominated swamp and the <i>Xerochloa</i> grasslands that occur within the Project Area would be located entirely within areas to be conserved. Approximately 293 hectares of <i>melaleuca minutifolia</i> low woodland would be subject to development while approximately 262 hectares would be located within conservation areas within the Project Area.	The environmental management proposed for this factor is described above under the factor of biodiversity.	The EPA’s objectives can be met with the project development plan by conserving and managing viable representative areas of vegetation communities that occur in the Project Area. All of the vegetation communities associated with riparian areas, including the <i>Echinochloa kimberleyensis</i> swamp near the foothills of the Weaber Range, and rock outcrops would be conserved to their full extent in the Project Area. The area of <i>melaleuca minutifolia</i> low woodland and <i>Xerochloa</i> grasslands conserved in the Northern Territory would increase. The biodiversity and health of vegetation associations in the conservation areas should improve with removal of cattle and management for conservation.
	Declared Rare and Priority Flora	Protect Declared Rare and Priority Flora, consistent with the provisions of the WA Wildlife Conservation Act 1950 and other relevant State, Northern Territory and Commonwealth legislation.	The Project Area is known to contain no Declared Rare Flora and 4 Priority Flora listed by the Western Australia Government and thirteen 3r flora and one insufficiently known nationally flora listed by the Northern Territory Governments. The Northern Territory list includes three taxa listed as being restricted in Central Australia but common throughout the remainder of the Territory. One taxon located in the Project Area—a grass (<i>Lepturus</i> sp. Mataranka ST Blake 17154)—is also listed by the Australian New Zealand Environment and Conservation Council Flora List as being endangered (Environment Australia 1999). Only four of the listed taxa have been recorded as only	Reduction in size of ecosystems for those species that occur on cracking clay soils. Approximately 25% of the cracking clay soils in the Project Area would be retained and managed for conservation. Grazing pressure from stock would be removed from the conservation areas. These areas would also be monitored and managed for weeds. The area known for the species <i>Lepturus</i> sp. Mataranka would be included in a conservation area.	The environmental management proposed for this factor is described above under the factor of biodiversity	The EPA’s objectives can be met with the project development plan.

Factor	Site Specific Factor	WA EPA objective	Existing Environment	Potential Impact	Environmental management	Predicted Outcome
			occurring on cracking clay soils. Another seven taxa are known to occur on cracking clay soils as well as other soils while eight taxa have not been recorded on cracking clay soils.			
Estuarine flora	Estuarine flora	Maintain the ecological function, abundance, species diversity and geographic distribution of estuarine and marine flora.	A number of species of mangrove are known to occur along the Keep River: <i>Avicennia marina</i> (white mangrove), <i>Bruguiera exaristata</i> (ribbed-fruited orange mangrove), <i>Ceriops tagal</i> var. <i>australis</i> (yellow mangrove), <i>Rhizophora stylosa</i> (red mangrove) and <i>Xylocarpus moluccensis</i> (cedar mangrove). However, only seedlings of <i>Avicennia marina</i> were located by survey along the Keep River within the Project Area. Mudflats occur downstream of the Project Area and at the Mouth of the Keep River.	All estuarine flora is located well outside of the area proposed for development, hence direct impact would not occur. Estuarine flora within the Project Area would be retained and managed for conservation. Potential exists for secondary impacts from changes to the hydrology (quantity and quality) of the Keep River. This potential is low, commensurate with the low level of impact predicted for the river's hydrology.	The environmental management for this factor would involve: - measures described above under the factor of biodiversity; - measures described below under the factor of surface water quality.	No impact on estuarine flora is predicted, hence the EPA's objective can be met with the project development plan.
Terrestrial fauna	Terrestrial fauna	Maintain the abundance of species diversity and geographical distribution of terrestrial fauna.	The fauna habitats of the Project Area comprises rock outcrop (6%), woodland (76%), grassland (5%), riverine woodland (8%), wetland (0.1%) and mudflats (5%). Surveys of the Project Area have recorded twenty-eight species of native mammals; two species of introduced mammals, 159 species of birds, forty-five species of reptiles and twenty species of frogs. Analysis of species composition for the habitat types results in the following conclusions: rock outcrops and wetland habitats show a distinct difference for mammals to other habitat types which can all be considered to be similar; the composition of birds between habitats varies little during the dry season. The results also indicate that bird assemblages may be more habitat specific during the wet season; rock outcrop habitat showed the strongest grouping for reptiles and frogs but there was only limited separation between all habitats.	The proposed development would require clearing of approximately 34,800 hectares of predominately black soil plains. These cracking clays are typically dominated by savanna woodland, and homogenous habitat consisting of Bauhinia woodland, eucalypt woodland and grassland. Approximately 40,960 hectares of land within the Project Area, comprising black soil plains and all of the riparian areas and rock outcrops would be managed for conservation.	The environmental management proposed for this factor is described above under the factor of biodiversity.	The proposed conservation areas contain fauna habitats that are representative of those found in the Project Area. Black soil plain, the predominant soil type targeted for development would have approximately 25% of its extent in the Project Area retained and managed for conservation. Habitat types that have been shown to have the strongest groupings for terrestrial fauna rock outcrops and wetlands would have the full extent in the Project Area retained for conservation. The EPA's objective can therefore be met.
	Specially protected (threatened) fauna	Protected Specially protected (Threatened) Fauna, consistent with the provisions of the WA Wildlife Conservation Act 1950 and other relevant State, Northern Territory and Commonwealth legislation.	A total of fifty-four vertebrate species considered rare or protected under Commonwealth and State legislation or listed in international treaties could be expected to be found in the Project Area. These include six mammals, forty-one birds, four reptiles and three frogs. Only nine of these species have actually been recorded within the Project Area: - Under the <i>Commonwealth Endangered Species Protection Act 1992</i> are listed Derby white-browed robin (<i>Poecilodryas superciliosa</i>) which is classified as endangered, and ghost bat (<i>Macroderma gigas</i>) which is considered vulnerable. - Black bittern (<i>Ixobrychus flavicollis gouldi</i>) is listed as Schedule 1 under the Western Australian Wildlife Conservation act 1950, while under Schedule 4 are listed peregrine falcon (<i>Falco peregrinus</i>), radjah shelduck (<i>Tadorna radja</i>), freshwater crocodile (<i>Crocodylus johnstoni</i>) and saltwater crocodile (<i>Crocodylus porosus</i>). - Ghost bat (<i>Macroderma gigas</i>), zitting cisticola (<i>Cisticola juncidis</i>) and wailing frog (<i>Cyclorana vagitus</i>) are listed under Schedule 7 of the <i>Parks and Wildlife Conservation Action 1993</i>.	The proposed development would require clearing of approximately 34,800 hectares of predominately black soil plains. These cracking clays are typically dominated by savanna woodland, a homogenous habitat consisting of Bauhinia woodland, eucalypt woodland and grassland. Approximately 40,960 hectares of land within the Project Area, comprising black soil plains and all of the riparian areas and rock outcrops would be managed for conservation.	The environmental management proposed for this factor is described above under the factor of biodiversity.	All the fauna habitat types of the Project Area would be represented in conservation areas. Habitats considered to include site-specific species would have all of their habitat conserved. Rare and specially protected fauna that could occur within the Project Area would have at least 42% of their habitat conserved. The project development plan can fulfill the provision of the Wildlife Conservation Act 1950; hence the EPA's objective can be met.
	Subterranean fauna	Maintain the abundance, species diversity and geographical distribution of subterranean species.	Little is known of the subterranean fauna of the Project Area. Limited sampling of a paleochannel beneath the Weaver Plain has indicated the presence of at least one species of bathynellid syncarid Crustacea. Similar fauna has been sampled from groundwater beneath ORIA Stage One, although it is unknown if the fauna from both areas is the same.	Project development would cause a change in the hydrogeological environment of the Project Area. This change would predominantly comprise an increase in groundwater and localised changes in groundwater quality. Groundwater salinity is expected to remain	The environmental management proposal for this factor is described below under the factor Groundwater quantity.	Potential impacts would appear to be restricted to changes in distribution reflecting localised changes in groundwater quality.

Factor	Site Specific Factor	WA EPA objective	Existing Environment	Potential Impact	Environmental management	Predicted Outcome
				within the natural range for groundwater in the Project Area and significant changes to groundwater quality arising from the use of farm chemicals are not predicted to occur. Existing stygofauna habitats would remain flooded.		
Aquatic fauna	Aquatic fauna	Maintain the ecological function, abundance, species diversity and geographic distribution of aquatic fauna.	A survey of the Keep River and Sandy Creek recorded five mammals, ninety-three birds, thirteen reptiles, eleven frogs and thirty-five fish species. The survey results indicated that the aquatic invertebrates comprise assemblages typical of Northern Territory rivers, creeks and billabongs. Insects and molluscs are common in most waterbodies and some insects are locally common. Two species of sawfish have been recorded in the Keep River—dwarf sawfish (<i>Pristis clavata</i>) and freshwater sawfish (<i>Pristis microdon</i>). Dwarf sawfish is coastal in distribution but can travel long distances up rivers into fresh water. Its conservation status is unknown but it may only occur in northern Australia. Freshwater sawfish is listed as ‘Endangered’ in the IUCN’s Red List, and as ‘Potentially threatened’ in the 1998 Australian Society for Fish Biology’s Threatened Fish List. It is usually located in fresh water and in the upper reaches of estuaries, and may be isolated in small billabongs for several years until floods release it back into the estuary. It has been recorded from several rivers in Western Australia, the Northern Territory and at Cape York in Queensland.	The proposed conservation areas would include all significant waterways, billabongs and wetlands, and their associated riparian vegetation. Direct impacts upon the habitats of fish and other aquatic biota would therefore be avoided, except in two localised areas associated with the road crossings of the Keep River and Knox Creek. Predicted changes to the hydrology of the Keep River and Sandy Creek from proposed development would be contained to the lower reaches of these watercourses and would involve: - an insignificant change in water quality; - a minor increase in peak flood velocities and an increase in the occurrence of peak flood levels; An increase in average flows during the wet season, and infrequent and minor releases of good quality water during the dry season.	The environmental management proposed for this factor is described below under the factor of Surface water quality.	The predicted changes are not expected to result in any significant impacts on fish and other aquatic biota in the Keep River and Sandy Creek. The altered flow regime may cause some localised erosion, but this would be monitored and managed to stabilise with time. The differential effect of the increased average flows would be greater in drier years and, at these times, the additional flows that would occur earlier and later in the wet season would benefit an environment that would otherwise be under stress.
Wetlands	Wetlands	To protect the environmental values and maintain or enhance key ecological functions of the wetlands.	A total of twenty-eight natural and one man-made wetlands have been identified in the Project Area. Most of these are associated with watercourses or are located at the base of rock outcrops. Throughout the Project Area the vegetation fringing the creeks, rivers and other watercourses is dominated by <i>Barringtonia acutangula</i> (freshwater mangrove), <i>Melaleuca argentea</i> (paperbark), <i>Pandanus spiralis</i> (screw palm), <i>Carthorium umbellatum</i>, <i>Acacia coleii</i> (wattle) and <i>Eucalyptus</i> spp., including <i>Eucalyptus camaldulensis</i> and <i>Excoecaria parvifolia</i> (guttapercha tree). These species are mainly associated with fresh or slightly brackish water. Scattered mangroves occur along the northern reaches of the Keep River within the Project Area, but extensive mangrove woodlands are located further downstream and outside the Project Area.	All of the natural wetlands in the Project Area would be retained and managed for conservation. Direct impacts would therefore not occur to these wetlands. Secondary impacts associated with changes in surface water and groundwater hydrology are possible.	The environmental management proposed for this factor would include: - inclusion of all natural wetlands and watercourses in the conservation area as described above under the factor of Biodiversity; - the management of groundwater levels as described below under the factor of Groundwater quality; - the strategic positioning of flood protection levees to minimise the changes to the hydrology of Keep River and its tributaries; - the implementation of on-farm water management measures as described below under the factor of surface water quality.	Minimal impact is predicted on the environmental values and functions of natural wetlands. These values and functions would be enhanced by removal of stock and management of weeds and access. The man-made wetland would be developed.
	Watercourses	Maintain the integrity, functions and environmental values of watercourses.	All of the watercourses in the Project Area only flow during the wet season. During the dry season the stream inverts are dry with the exception of localised rocky pools and the tidal sections of the Keep River and Sandy Creek. The riparian vegetation is described above under the factor of Wetlands.	Potential impacts arise from the construction of flood protection levees, which would increase the magnitude of frequently occurring floods, possibly leading to increases in erosion. Farm development would also increase the average annual volume of run-off reaching the Keep River. Rises in groundwater levels may cause some induced base flow in the lower reaches of the Keep River and Sandy Creek.	Hydrology models have been used to strategically locate flood protection levees so as to minimise increases in flood heights and velocities for frequently occurring floods. All riparian areas would be retained and managed for conservation. Management would include monitoring for erosion and remediation measures as appropriate. Monitoring would also include the effects on riparian vegetation of any groundwater induced stream flow. Groundwater management using dewatering bores would be implemented’ as required.	Peak flood levels from frequently occurring floods would be restricted to less frequently occurring levels. Minor increases in peak flood velocity are predicted at some locations and where the substrates are not rock, the increased velocities are within ranges that do not generally cause erosion. Levees have been positioned to avoid frequent inundation of Point Spring Nature Reserve.
	Groundwater quantity	Maintain groundwater so that existing and potential uses, including ecosystem maintenance are protected.	Groundwater flow occurs in paleochannels beneath each of the three plains that could be developed. Beneath the Weaber Plain the groundwater flow is generally west to east while under the Knox Creek and Keep River plains the general direction of groundwater flow is to the north. Groundwater levels are generally approximately 20 m below the surface of the Weaber Plain, 10–15 m below the surface of the Knox Creek Plain and 5–10 m below the surface of the Keep River Plain.	Groundwater level rise due to increased accessions from the surface.	A proactive groundwater management strategy is proposed as part of the Project. This strategy seeks to manage groundwater levels from project inception to ensure the sustainability of irrigated agriculture on the Project Area. Engineering design standards would comply with current best practice for all irrigation channels and regulating storage’s intended to convey or store water for prolonged periods. Crop watering strategies that maximise the water uptake by crops and minimise the water loss to groundwater would be	Groundwater levels are predicted to rise but be controlled in the long term to greater than 5 m from the surface over most of the Project Area.

Factor	Site Specific Factor	WA EPA objective	Existing Environment	Potential Impact	Environmental management	Predicted Outcome
					utilised. Groundwater levels would be controlled via the utilisation of bores and subsoil drains. A comprehensive monitoring programme for groundwater levels and quality would be implemented and the collected data used to modify management practices as necessary.	
	Surfacewater quantity	Maintain surface water so that existing and potential uses, including ecosystem maintenance are protected.	All of the watercourses in the Project Area only flow during the wet season. During the dry season the stream inverts are dry with the exception of localised rocky pools and the tidal sections of the Keep River and Sandy Creek.	Increase in wet season flows of the Keep River and Sandy Creek due to provision improved drainage to the project development area.	The environmental management prepared for this factor is described below under the factor of surface water quality.	The net result of the Project would be an increase in the volume of run-off reaching streams and rivers over the wet season. On average, an annual flow increase of about 20% in the lower reaches of the Keep River is predicted. The timing of runoff flows leaving the Project Area would also change following development due to the cropped areas entering the wet season in a moist state and the improved efficiency of the drainage infrastructure. The magnitude of this change would vary, however, it is probable that in some seasons the runoff from the cropped areas would occur around one month earlier than is currently the case.
	Mosquitoes and disease vectors	Mosquito numbers on-site should not adversely affect the health, welfare and amenity of future residents; and Ensure the breeding of mosquitoes is controlled to the satisfaction of the Health Department without adversely affecting other flora and fauna.	The flavivirus, which causes Murray Valley encephalitis, and the alphavirus, which causes Ross River virus, are the two most important pathogenic arboviruses causing human disease in Australia. Both are enzootic (always present) in the east Kimberley. Barmah forest virus has also been recorded in the Ord River area. The mosquito Culex annulirostris is an important vector of both the Murray Valley encephalitis virus and the Ross River virus. Culex annulirostris breeds in fresh water and is the predominant species of mosquito found in the Ord River area. The numbers of mosquitoes vary widely from year to year but the highest numbers correspond to years with heavy wet season rainfall.	An increase in the number of mosquito related diseases due to a combination of: - an increase in the number of residents in the region; - possible increase in mosquito populations.	Management action would be taken as part of the Project to reduce the risk of increased infection with arboviruses. These actions would concentrate upon the following activities: - designing and operating the Project so as to reduce the potential for increased mosquito-breeding activity; - implementing education programmes for the Project's construction and operational workforce on measures that could be taken to reduce their personal risk of infection; - extending the existing monitoring programmes to cover the Project Area.	A potential increase in the number of mosquito related diseases.
Land	Hydrology	Establish stable, sustainable landform consistent with surroundings.	The Project Area generally comprises fine-textured fluvial plains of the Ivanhoe Land System that are flat to gently undulating, with localised variation in topography and soil types. Surrounding the Project Area are the following landforms: - the Cockatoo Land System, made up of gently undulating plains on sandstone and calcareous sandstone, or deep sands; - rugged hilly country with ridges, hogbacks, cuestas and structural plateaux of the sandstone, calcareous sandstone and conglomerate rock outcrops of the Weaver Land System, or of the sandstone, siltstone and shale rock outcrops and skeletal soils of the Pinkerton Land System; - gently sloping alluvium with leached yellowish loamy and sandy soils of the Angallari Land System and undulating plains on dolomite and shale, leached loamy soils with moderate limestone outcrop of the Dinnabung Land System; - estuarine alluvium cracking clay and solonchets soils of the Legume Land System; - estuarine alluvial plains, saline soils and bare mud of the Carpentaria Land System.	Erosion from areas disturbed by construction activities.	Soil erosion in the Project Area would be controlled by a combination of the following management strategies: - controlling drainage by providing levee banks to prevent floodwaters entering the developed area; - grading land on farms to gentle slopes to minimise stormwater runoff velocities; - sizing and designing receiving drains to accommodate anticipated flow regimes; - providing buffer zones on both sides of watercourses to allow riparian vegetation to continue to stabilise soils in these areas; - rehabilitating disturbed areas: - as soon as possible following disturbance during construction; - by formulating and implementing appropriate rehabilitation plans and programmes including topsoil stripping and stockpiling, land preparation, and reseedling to facilitate regeneration of disturbed areas; - managing crops in such a way that crop cover of the soil is maximised, particularly during the wet season when highly erosive rainfall may occur. Monitoring and remediation of erosion would also occur as part of normal operations within the Project Area.	The landforms within the Project Area would be modified from the existing primarily natural state to become a highly managed agricultural landscape. The drainage patterns of the plains would be modified to provide a more consistent gradient and to facilitate optimum water application and drainage. In addition, a formal drainage system would be developed within and around the Project Area.

Factor	Site Specific Factor	WA EPA objective	Existing Environment	Potential Impact	Environmental management	Predicted Outcome
Pollution Management						
Air	Particulates and dust	Ensure that the dust levels generated by the proposal do not adversely impact welfare and amenity of surrounding land users or cause health problems by meeting statutory requirements and acceptable standards.	Ambient levels of dust in the Project Area are likely to be highly seasonal, with low levels during the wet season, increasing during the dry season as the cover of native vegetation becomes substantially less and wind strength increases. Movements of vehicles on unsealed roads and stock movements would be localised sources of dust.	Increased nuisance from dust, although the potential is very low due to the remoteness of the Project Area from existing residences.	The main issue associated with dust would be the protection of workers from excessive levels. Earth-moving contracts would be structured to require air-conditioned cabins on earth moving equipment and monitoring of dust levels associated with development activities. A dust-monitoring programme would be established as part of the EMP and administered throughout the construction and operational phases of the Project. Emissions from the sugar mill would be passed through a scrubber in order to reduce particulate emissions from that source to levels within national guideline levels.	Remoteness of the site should mitigate issues associated with nuisance dust.
	Chemical spray drift	Ensure that spray drift generated by chemicals used for the proposal does not adversely impact health, welfare and amenity of surrounding land users and the environment by meeting statutory requirements and acceptable standards.	Chemical sprays are currently not used in the Project Area. However, chemical sprays are currently used in ORIA Stage One, which is located closer to the residential area of Kununurra than the Project Area.	Existing residences are located well outside the expected range of spray drift from the Project Area. Entry of chemicals into the environment may occur via watercourses.	In order to minimise the potential for spray drift, the application of chemicals within the Project Area would, wherever possible, be from tractor-drawn boom-sprays utilising technology that results in relatively large spray droplets being released close to the ground. In other circumstances, for example when ground or crop conditions prevent tractor access, it may be necessary to utilise aerial spraying. In these instances only operators who have successfully undertaken the pilot accreditation programme of the Aerial Agricultural Association of Australia would be utilised, and the timing and manner of application would be carefully chosen to minimise spray drift. The provision of a nominal 1,500 m buffer zone around the farm areas would avoid future land use conflicts.	The use of agricultural chemicals within the Project Area would be minimal in relation to other agricultural industries in Australia. Sugarcane, the dominant crop proposed for the Project Area, has a low requirement for pesticides. Furthermore, the Project Area and its surrounds are characterised by sparse residential settlement. As a consequence of the above factors, the potential for detrimental impact to surrounding land users from the usage of agricultural chemicals in the Project Area is considered low.
	Greenhouse gases	Ensure that greenhouse gas emissions meet acceptable standards and requirements of Section 51 of the WA Environmental Protection Act 1986 (all reasonable and practicable measures are taken to minimise greenhouse gas discharge).	The Project Area has been assumed to be in equilibrium with respect to greenhouse gas emissions.	Clearing of native vegetation comprising savanna woodland and grasslands. However, most the Project Area would be developed for the cultivation of sugarcane, a perennial crop with a greater biomass per unit area than the existing vegetation.	Processing of sugar cane to produce raw sugar would utilise the bagasse bi-product as the primary source of fuel. Large scale farm machinery and trucks would be utilised to improve the efficiency of agricultural and transport operations with respect to fuel use.	A net increase is predicted in the amount of carbon sequestered in vegetation in the Project Area following development. In addition, the carbon sequestered in the raw sugar and molasses products would exceed the carbon released from the consumption of fuel by agricultural and transport operations. The Project Area is closer to intended markets in Asia than alternative producers, providing the potential for reductions in greenhouse gas emissions from the shipping of products.
Water	Groundwater quality	Maintain or improve the quality of groundwater to ensure that existing and potential uses, including ecosystem maintenance are protected.	Groundwater quality of the Project Area varies with location. Groundwater of the Weaber Plain has a salinity range of 70mg/L to 2,600mg/L TDS. The salinity of groundwater of the Knox Creek Plain is generally around 1,000mg/L but can range from 60mg/L to 20,800mg/L TDS. The groundwater salinity beneath the Keep River Plain varies greatly, ranging between 100mg/L to 51,000mg/L TDS. Surface expressions of groundwater at Cave Spring and Point Spring are from different aquifers to those beneath the Project Area. The groundwater of the Project Area is not known to support ecosystems, other than stygofauna.	Localised changes in groundwater salinity due to accessions from cropped areas and irrigation and drainage infrastructure. Potential migration of agricultural chemicals from the surface.	The focus of groundwater management would be on controlling groundwater levels as discussed above under the factor of Groundwater quantity. The black soil plains that would be the target for development are known to be highly effective in binding herbicides, pesticides and phosphorous and restricting their migration to groundwater. Monitoring of groundwater quality would be a component of the EMP.	In the long term the salinity of the groundwater would trend towards the salinity of all the accessions would trend combined, which are predicted to be less than 2,200mg/L TDS. Localised areas of lower salinity would still occur in areas where the predominant accessions would be from irrigation and drainage infrastructure. The predicted levels are within the range of naturally occurring levels. The black soils typical of the Project Area are known to be highly effective in binding phosphorus, and elevated levels of this nutrient are not anticipated in the groundwater beneath the Project Area. Nitrogen levels in groundwater are predicted to be in the range of 3.1–5.2 mg/L. Although the predicted levels are about twice the naturally occurring levels, they remain relatively low. For example, the drinking-water guideline value is 10 mg/L. Elevated levels of pesticides are not predicted for groundwater of the Project Area.

Factor	Site Specific Factor	WA EPA objective	Existing Environment	Potential Impact	Environmental management	Predicted Outcome
	Surface water quality	Maintain or improve the quality of surface water to ensure that existing and potential uses, including ecosystem maintenance are protected.	Monitoring of wet season flows in the Project Area has shown that these flows naturally contain high levels of suspended solids and often contain natural levels of nutrients phosphorus and nitrogen that exceed national guideline values for the protection of aquatic ecosystems.	Reduction in water quality from the migration of sediment, fertilisers and pesticides from the farm areas.	All farm units within the Project Area would be developed with tailwater return systems capable of collecting and returning on-farm all irrigation water runoff. The tailwater return systems would be designed in such a way as to also perform the function of first-flush stormwater collection systems, with the collected stormwater also being returned on-farm for use as irrigation water. Recent advances achieved in pesticide use and management in ORIA Stage One would be adopted, and wherever possible enhanced, in the Project Area. As a minimum this would include: • provision of buffers between farms and water courses; • the adoption of the integrated pest management strategy developed in ORIA Stage One where appropriate; • the adoption of the spray calendar developed each year for ORIA Stage One; • the adoption of AGWEST recommendations for on-farm management of endosulfan; • compulsory training for all farm staff who would be required to handle and spray chemicals; • compulsory accreditation of all commercial spray operators to a national standards system. In addition, the above management measures would be supported by a comprehensive monitoring programme for pesticides and chemicals in the receiving environment.	Levels of sediment and nutrients in surface waters are predicted to remain within the naturally occurring range. Levels of farm chemicals, including pesticides, are predicted to be within national guideline values for maintenance of aquatic ecosystems.
Social Surroundings						
Recreation	Recreation	Maintain or enhance recreational usage of the Project Area, consistent with plans developed by planning agencies.	There are no existing plans that have been developed by planning agencies for the land within the Project Area, apart from the Point Springs Nature Reserve managed by CALM. Limited access to the pastoral leases due to locked gates, poorly maintained roads and limited access points to the Keep River	Community access to the black soil plains would be limited to the Conservation Area due to the establishment of the farms. Community access to the Keep River would be improved due to maintained roads. Management of the land would be improved due to the establishment of an Environmental Management Entity. Safety to travelers would be enhanced due to an improved and maintained road system.	The Conservation Area would be managed by the Environmental Management Entity. Miriung and Gajerrong people would be invited to participate in management. Specific recreation areas including localities on the Keep River would be established and managed.	Increased visitation of the Project Area by local residents and tourists. Improved access to and management of recreational areas. Active involvement of Miriung and Gajerrong people in the management of their native title rights. Increased opportunity for recreation associated industries and employment. Increased opportunity for people to learn about the natural environment.
Culture and heritage	Aboriginal heritage and culture	Ensure the proposal complies with the requirements of the Aboriginal Heritage Act 1972; and Ensure that changes to the biological and physical environment resulting from the project do not adversely affect cultural associations with the area.	No active management of cultural heritage sites is presently undertaken by the State, Territory or Commonwealth heritage agencies. Limited opportunity for Miriung and Gajerrong people to presently be consulted or invited to be involved in the management of the cultural and biophysical environment.	Compliance with State, Territory and Commonwealth legislation as well as the rights of native titleholders would occur. Known cultural heritage sites would be located, recorded and protected. Cultural heritage sites would not be affected by the development of the infrastructure corridor or the Sugar Mill site. Miriung and Gajerrong people would have the opportunity to have input into the management of cultural heritage sites.	The Cultural Heritage Management Plan would be developed as part of the Environmental Management Plan to be administered by the Environmental Management Entity. Miriung and Gajerrong people would have the opportunity to be involved in the development of the Plan as well as the operation of the Environmental Management Entity. Cultural heritage sites would be managed using appropriate techniques agreed with the endorsement of Miriung and Gajerrong people, and the State, Territory and Commonwealth heritage agencies. Aboriginal Areas Protection Authority issued Authority Certificates for the NT portion of the Project Area.	Undertake an additional cultural heritage assessment of the land to be developed. Develop a Cultural Heritage Management Plan to ensure that sites are managed and protected, lessening any inadvertent damage. Involvement of Miriung and Gajerrong people in the management of cultural heritage sites. Increase community awareness regarding Aboriginal cultural heritage values in the area.
Social	Social surrounds	To maintain and protect the aesthetic, cultural, economic and social surroundings, where those surroundings affect or are affected by physical and biological changes.	Limited community understanding of the aesthetic, cultural, economic and social surroundings that will be affected.	Change from land containing pastoral activity to irrigated farmland. Establishment of new bodies of water would encourage an increase in fauna. Long-term environmental management would provide the opportunity for Miriung and Gajerrong people to be involved. Native title over the developed land may be extinguished while rights over the non-	The farmland would be managed by the individual owners. The undeveloped land contained within the Conservation area would be managed by the Environmental Management Entity. Miriung and Gajerrong people would have the opportunity to participate in management. A Cultural Heritage Management Plan would be developed detailing an agreed process for sustainable management. Conservation Reserves/National Park would be co-operatively managed by the NT and WA Governments with input from the	Establishment of the Environmental Management Entity. Development of the Environmental Management Plan that reflects the native title rights of Miriung and Gajerrong people. Development of a Cultural Heritage Management Plan. Conclusion of an Aboriginal Socio-Economic Impact Assessment of the impacts on Miriung

Factor	Site Specific Factor	WA EPA objective	Existing Environment	Potential Impact	Environmental management	Predicted Outcome
				developed land would be maintained. Increase in land available for Conservation Reserve or National park as a direct result of the development of the Project.	Miriuwung and Gajerrong people.	and Gajerrong people. Maximise the positive impacts and minimise the negative impacts of the Project on Miriuwung and Gajerrong people. Settle an Indigenous Land Use Agreement to address and compensate Miriuwung and Gajerrong people for the extinguishment or impairment of native title rights. The ILUA would ensure the active involvement of Miriuwung and Gajerrong people in the management of the Conservation Reserve and the National Park.
Cumulative Impact	None	None		Increased allocation of water from the Ord River for other ORIA Stage 2 proposals resulting in less water being available for environmental flow. Increased clearing of native vegetation in the Victoria-Bonaparte Biogeographic region.	The Water and Rivers Commission has commenced a process to allocate water from the Ord River that will address environmental needs and the combined effect of the Project and other development. This proposal is consistent with the Commission's Interim Water Allocation Plan. The proposal involves the conservation of unique and representative samples of vegetation species and communities within the Project Area.	A comparison of the results of biological survey shows that while there is a significant overlap in floristic composition between the Project Area and other ORIA Stage 2 development, the sites are clearly separated in biological terms. The strategy of conserving representative and reasonably sized viable portions of vegetation associations and fauna habitats should therefore be an effective means of mitigating combined regional vegetation clearance effects.

Factor	Site Specific Factor	WA EPA objective	Existing Environment	Potential Impact	Environmental management	Predicted Outcome
		ecosystem maintenance are protected.	and nitrogen that exceed national guideline values for the protection of aquatic ecosystems.		return systems would be designed in such a way as to also perform the function of first-flush stormwater collection systems, with the collected stormwater also being returned on-farm for use as irrigation water. Recent advances achieved in pesticide use and management in ORIA Stage One would be adopted, and wherever possible enhanced, in the Project Area. As a minimum this would include: • provision of buffers between farms and water courses; • the adoption of the integrated pest management strategy developed in ORIA Stage One where appropriate; • the adoption of the spray calendar developed each year for ORIA Stage One; • the adoption of AGWEST recommendations for on-farm management of endosulfan; • compulsory training for all farm staff who would be required to handle and spray chemicals; • compulsory accreditation of all commercial spray operators to a national standards system. In addition, the above management measures would be supported by a comprehensive monitoring programme for pesticides and chemicals in the receiving environment.	including pesticides, are predicted to be within national guideline values for maintenance of aquatic ecosystems.
Social Surroundings						
Recreation	Recreation	Maintain or enhance recreational usage of the Project Area, consistent with plans developed by planning agencies.	There are no existing plans that have been developed by planning agencies for the land within the Project Area, apart from the Point Springs Nature Reserve managed by CALM. Limited access to the pastoral leases due to locked gates, poorly maintained roads and limited access points to the Keep River	Community access to the black soil plains would be limited to the Conservation Area due to the establishment of the farms. Community access to the Keep River would be improved due to maintained roads. Management of the land would be improved due to the establishment of an Environmental Management Entity. Safety to travelers would be enhanced due to an improved and maintained road system.	The Conservation Area would be managed by the Environmental Management Entity. Miriung and Gajerrong people would be invited to participate in management. Specific recreation areas including localities on the Keep River would be established and managed.	Increased visitation of the Project Area by local residents and tourists. Improved access to and management of recreational areas. Active involvement of Miriung and Gajerrong people in the management of their native title rights. Increased opportunity for recreation associated industries and employment. Increased opportunity for people to learn about the <u>natural environment</u> .
Culture and heritage	Aboriginal heritage and culture	Ensure the proposal complies with the requirements of the Aboriginal Heritage Act 1972; and Ensure that changes to the biological and physical environment resulting from the project do not adversely affect cultural associations with the area.	No active management of cultural heritage sites is presently undertaken by the State, Territory or Commonwealth heritage agencies. Limited opportunity for Miriung and Gajerrong people to presently be consulted or invited to be involved in the management of the cultural and biophysical environment.	Compliance with State, Territory and Commonwealth legislation as well as the rights of native titleholders would occur. Known cultural heritage sites would be located, recorded and protected. Cultural heritage sites would not be affected by the development of the infrastructure corridor or the Sugar Mill site. Miriung and Gajerrong people would have the opportunity to have input into the management of cultural heritage sites.	The Cultural Heritage Management Plan would be developed as part of the Environmental Management Plan to be administered by the Environmental Management Entity. Miriung and Gajerrong people would have the opportunity to be involved in the development of the Plan as well as the operation of the Environmental Management Entity. Cultural heritage sites would be managed using appropriate techniques agreed with the endorsement of Miriung and Gajerrong people, and the State, Territory and Commonwealth heritage agencies. Aboriginal Areas Protection Authority issued Authority Certificates for the NT portion of the Project Area.	Undertake an additional cultural heritage assessment of the land to be developed. Develop a Cultural Heritage Management Plan to ensure that sites are managed and protected, lessening any inadvertent damage. Involvement of Miriung and Gajerrong people in the management of cultural heritage sites. Increase community awareness regarding Aboriginal cultural heritage values in the area.
Social	Social surrounds	To maintain and protect the aesthetic, cultural, economic and social surroundings, where those surroundings affect or are affected by physical and biological changes.	Limited community understanding of the aesthetic, cultural, economic and social surroundings that will be affected.	Change from land containing pastoral activity to irrigated farmland. Establishment of new bodies of water would encourage an increase in fauna. Long-term environmental management would provide the opportunity for Miriung and Gajerrong people to be involved. Native title over the developed land may be extinguished while rights over the non-developed land would be maintained. Increase in land available for Conservation Reserve or National park as a direct result of the	The farmland would be managed by the individual owners. The undeveloped land contained within the Conservation area would be managed by the Environmental Management Entity. Miriung and Gajerrong people would have the opportunity to participate in management. A Cultural Heritage Management Plan would be developed detailing an agreed process for sustainable management. Conservation Reserves/National Park would be co-operatively managed by the NT and WA Governments with input from the Miriung and Gajerrong people.	Establishment of the Environmental Management Entity. Development of the Environmental Management Plan that reflects the native title rights of Miriung and Gajerrong people. Development of a Cultural Heritage Management Plan. Conclusion of an Aboriginal Socio-Economic Impact Assessment of the impacts on Miriung and Gajerrong people. Maximise the positive impacts and minimise the <u>negative impacts of the Project on Miriung and</u>

Factor	Site Specific Factor	WA EPA objective	Existing Environment	Potential Impact	Environmental management	Predicted Outcome
				development of the Project.		Gajerrong people. Settle an Indigenous Land Use Agreement to address and compensate Miriuwung and Gajerrong people for the extinguishment or impairment of native title rights. The ILUA would ensure the active involvement of Miriuwung and Gajerrong people in the management of the Conservation Reserve and the National Park.
Cumulative Impact	None	None		Increased allocation of water from the Ord River for other ORIA Stage 2 proposals resulting in less water being available for environmental flow. Increased clearing of native vegetation in the Victoria-Bonaparte Biogeographic region.	The Water and Rivers Commission has commenced a process to allocate water from the Ord River that will address environmental needs and the combined effect of the Project and other development. This proposal is consistent with the Commission's Interim Water Allocation Plan. The proposal involves the conservation of unique and representative samples of vegetation species and communities within the Project Area.	A comparison of the results of biological survey shows that while there is a significant overlap in floristic composition between the Project Area and other ORIA Stage 2 development, the sites are clearly separated in biological terms. The strategy of conserving representative and reasonably sized viable portions of vegetation associations and fauna habitats should therefore be an effective means of mitigating combined regional vegetation clearance effects.

1 Project objectives and background

This introductory chapter provides the background to the proposed development of the M2 area of the Ord River Irrigation Area Stage 2 (the Project). The chapter includes information on the co-proponents for the environmental assessment of the proposed development, Wesfarmers–Marubeni and the Water Corporation of Western Australia. The history of development of the Ord River Irrigation Scheme is provided together with a brief overview of the scope and timing of the proposed development. The chapter includes a discussion of the regulatory framework that would govern the Project and the environmental impact assessment process. It also includes a brief discussion on the world’s sugar markets, the consequences of not proceeding with the Project, and an outline of the scope and structure of this report.

1.1 THE EXISTING ORD RIVER IRRIGATION SCHEME

1.1.1 History of development

Basic research into irrigated agriculture in the East Kimberley began in 1941 when the Government of Western Australia established a small experimental farm on the banks of the Ord River, near to the off-take for the present main irrigation (M1) channel. This farm was abandoned in 1945 in favour of the Kimberley Research Station, which was developed on the Ivanhoe Plain as a joint Commonwealth–State venture.

Results of successful crop trials with rice, cotton, safflower, flax and sugarcane convinced the Western Australian Government that an irrigation scheme on the Ord River would be viable. Development of the Ord River Irrigation Scheme was planned to proceed in two stages. Ord River Irrigation Area Stage 1 (ORIA Stage 1) of the development was completed by 1966: this involved construction of the Kununurra Diversion Dam to form Lake Kununurra, as well as irrigation infrastructure and associated works, and the township of Kununurra (Figure 1.1). The cost then was about \$20 million, with the Commonwealth Government contributing \$12 million. By this time, thirty-one farms had been allocated on the Ivanhoe Plain, all irrigated from Lake Kununurra.

The second stage of the Ord River Irrigation Scheme has only been partially completed to date. Completed works include construction of the Ord River Dam—about 50 km upstream from Kununurra—to provide a major storage reservoir called Lake Argyle, at a cost of \$22 million. This dam was officially opened in 1972. A further 2,000 ha of land were also developed in 1974 on the Packsaddle Plain as part of Stage 2. About 14,000 ha are currently developed as irrigated farms.

Water is supplied to Lake Kununurra from Lake Argyle, with some of this flow being via a hydroelectric power station. From Lake Kununurra, irrigation water is mainly gravity fed to the farming areas, with some pumped supply to Packsaddle Plain and small areas of black soil, sand and levee soil. The Water Corporation is responsible for operating and maintaining the dams on the Ord River and the water distribution and drainage system.

In 1994 the height of the spillway in the Ord River Dam was raised as part of the works associated with installation of the hydroelectric power station. The storage capacity of the Ord River Dam is sufficient not only to supply the water requirements for all of the potential irrigation areas at a level of security better than 98%, but also to allow for the release of water to maintain environmental values in the Ord River downstream of Lake Kununurra (Chapter 5 refers).

1.1.2 Existing development

Existing developments that comprise the Ord River Irrigation Scheme include the following major components:

- irrigated agricultural land on the Ivanhoe Plain and the Packsaddle Plain;
- the Kununurra Diversion Dam on the Ord River that forms Lake Kununurra;
- the Ord River Dam that forms Lake Argyle;
- the township of Kununurra.

Irrigated farmland

A gross area of 14,000 ha of land has been developed for irrigated agriculture on the Ivanhoe Plain and the Packsaddle Plain. About 11,500 ha of this area is currently cropped, with the balance devoted to irrigation, drainage, access and farm infrastructure. Agricultural activities include broad-acre cropping of the cracking clay (black soil) areas with sugarcane, chick pea, pasture, melons and seed crops, and tree crops such as bananas and mangoes on lighter textured loam and sandy soils.

Both areas draw their irrigation water from Lake Kununurra via open channels with an overall length greater than 134 km. The Packsaddle Plain areas require some pumping of the irrigation water while the Ivanhoe Plain area is gravity fed via a system of channels, including the M1 Channel. A network of about 155 km of open channels collects drainage waters from both areas for discharge to the Ord River, downstream of the Kununurra Diversion Dam. Part of the Packsaddle Plain drains to the Dunham River, a tributary of the Ord River.

Early development of ORIA Stage 1 was beset with problems associated with control of pests and poor farm economics, mainly due to the remoteness of the area. Current farming activities have benefited from the experience gained during the difficult early years to the extent that they are now profitable. As a consequence there is now a strong demand for developed irrigation farmland in the region.

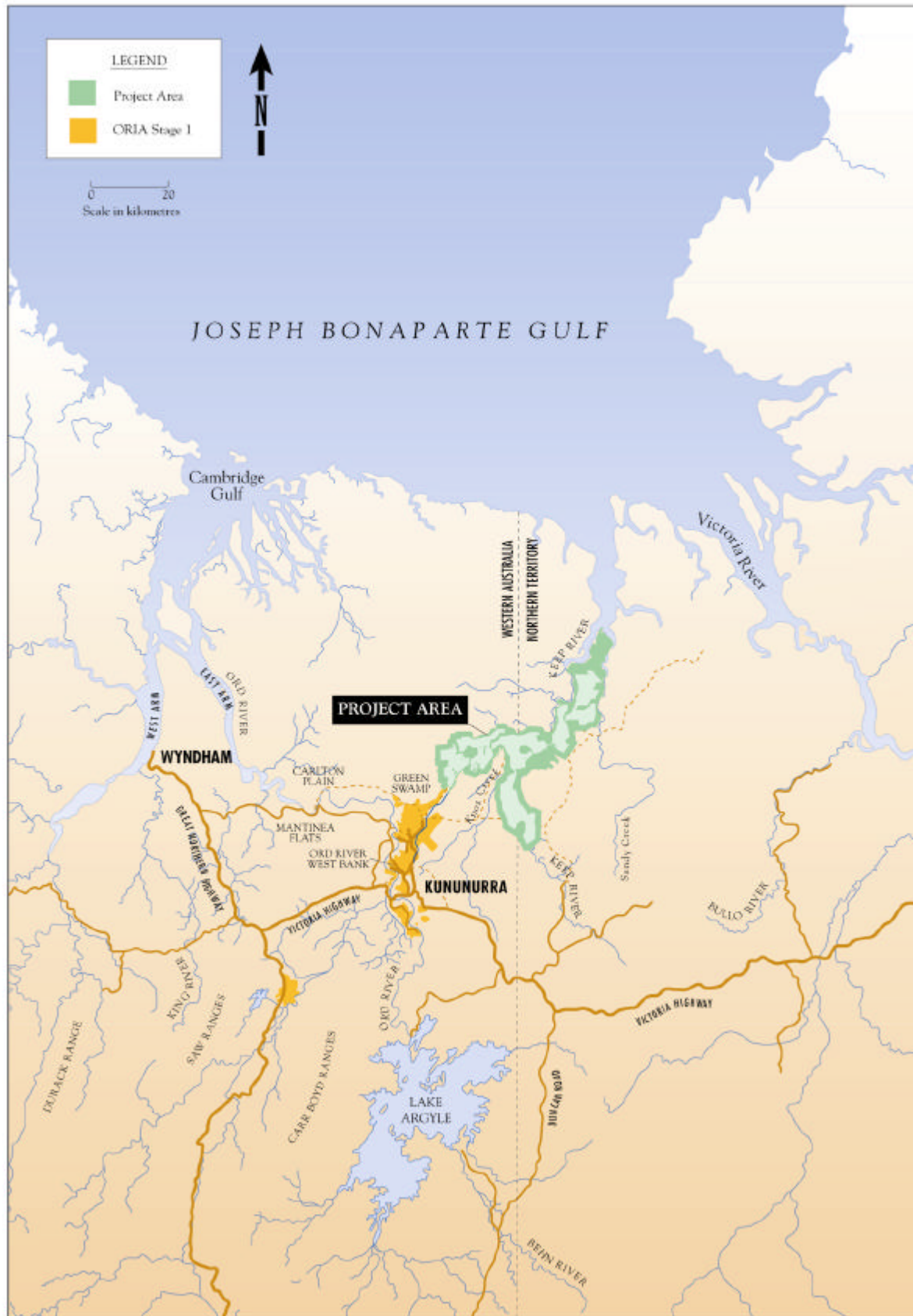


Figure 1.1 Overview of Ord Region and Project Area

Kununurra Diversion Dam

The purpose of the Kununurra Diversion Dam is to maintain water levels in Lake Kununurra sufficient to irrigate the existing ORIA Stage 1 areas and possible future irrigation areas on the Weaber, Keep River and Knox Creek plains. The Diversion Dam consists of a long concrete spillway with earth and rockfill embankments on each side. The spillway is a broad concrete sill keyed into the natural rock foundation. Set on top of the sill is a series of vertical piers between which are located large radial gates. The gates provide the barrier against which the water is stored. When required, they can be opened to allow the wet season floods to pass, or to release water to farmers drawing their supplies from the river downstream of the Diversion Dam. Spanning the Diversion Dam is a highway bridge, which provides all-weather road access across the Ord River.

Ord River Dam

The Ord River Dam, located some 50 km upstream of the Kununurra Diversion Dam, forms Lake Argyle, the principal water storage of the Ord River Irrigation Scheme. The water of this lake is also used for:

- generation of power in a 30 MW hydroelectric power station owned and operated by Ord Hydro Pty Ltd. This power is reticulated north to Kununurra and Wyndham and south to the Argyle Diamond Mine;
- commercial fishing based mainly upon netting of catfish species. A small barramundi fish-farming operation is also based on Lake Argyle, and Fisheries Western Australia (Fisheries) is currently investigating further development of fish-farming based upon this species;
- process and potable water (following treatment) at the Argyle Diamond Mine;
- tourism, recreation and the maintenance of environmental values in Lake Kununurra and the lower reaches of the Ord River.

Kununurra township

Kununurra is the regional centre for local, State and Commonwealth Government departments. Consequently, a relatively large proportion of the town's labour force is employed in the community services and public administration sectors.

Over the past ten years, the number of businesses in Kununurra has grown steadily. In particular, there has been an increase in the number of smaller specialist stores, supermarkets have been established, and the number of industries servicing the agricultural and tourism sector has grown.

1.1.3 Potential for expansion

Despite the completion of the Ord River Dam in 1972, the Ord River Irrigation Scheme has not yet been developed to fulfil its full potential. This, in the past, has been due to view held by the private sector and Government that projected economic returns from the full development of the Ord River Irrigation Scheme may not justify the significant investment that would be required. In recent years, the successful cultivation in the Ord River Irrigation Scheme of broadacre crops such as sugarcane, has resulted in a revisit of the opportunities to extend the Ord River Irrigation Scheme.

Completion of ORIA Stage 1 would involve the development of land at Green Location. The proposed Stage 2 developments include extensive areas of black soil on the Weaber, Keep River and Knox Creek plains, and development of land at Carlton Plain, Mantinea Flats and on the Ord River West Bank.

The development of irrigation farmland on the Weaber, Keep River and Knox Creek plains would require the development of a purpose-built irrigation channel from the existing water supply at Lake Kununurra. The proposed channel is known as the M2 Channel, and the area to be served by the channel as the M2 Development Area.

Irrigation water to serve proposed farm development at Carlton Plain, Mantinea Flats, Mantinea Loop and on the Ord River West Bank would be obtained by pumping from the Ord River downstream of Lake Kununurra. The aforementioned developments are known as the Riverside Developments.

This proposal refers only to the development area that would be served by the M2 Channel. The Riverside Developments and Green Swamp would be subject to separate environmental impact assessments by other proponents.

1.1.4 Development preliminaries

In 1994, the Western Australian Government committed to investigation of the extension of the Ord River Irrigation Scheme so that the scheme would fulfill its full potential.

As part of the proposed scheme lies within the Northern Territory, agreement was reached between the Western Australian and Northern Territory Governments to develop the whole scheme. Agreement between the Governments was reached in 1995, and the vision of the Governments with respect to the proposed extensions to the scheme was stated as follows (Government of Western Australia and Government of the Northern Territory, 1997):

‘The ORIA Stage 2 project will be developed to its full potential as quickly as possible in a manner that ensures long term economic and environmental sustainability. Net benefits to the local community, the State of Western Australia, the Northern Territory and Australia will be maximised by attracting the early involvement of competent commercial interests with established reputations, and by those involved adopting an open and communicative approach with all interested parties as the development proceeds.’

The key objectives of the Western Australian and Northern Territory Governments with respect to the development are as follows:

- maximise sustainable production and economic returns through the most efficient use of the available suitable irrigation land and water resources;
- maximise the involvement of private commercial interests in the development;
- adopt land release and pricing plans that accommodate a variety of land demands while maintaining economic viability of the proposed land uses;
- establish an environmental management framework prior to the commencement of developments, aiming to carefully monitor and manage any changes and minimise adverse environmental impacts;
- resolve native title and Aboriginal heritage issues equitably and without excessive delay;

- communicate openly and effectively during the course of development to retain consistent community support for the project;
- strive for maximum regional economic benefits.

Throughout 1995 and 1996, the Governments commissioned various preliminary studies in relation to the proposed development of Ord Stage 2, with a view to calling for registrations of interest from the private sector. Results from the preliminary studies proved sufficiently attractive for the Governments to call for private sector Registrations of Interest (1996) and Expressions of Interests (1997). One of the studies commissioned by the Governments was a draft Public Environmental Review (Section 1.4.2 refers).

The call for expressions of interest resulted in the submission of a number of detailed proposals from local and overseas-based organisations. In 1998, a joint venture between Wesfarmers Sugar Company Pty Ltd (Wesfarmers) and Marubeni Corporation (Marubeni) was awarded an exclusive mandate by the Governments to investigate the feasibility of development of the M2 Development Area for the purposes of broadacre irrigation (Sections 1.3.2 and 1.3.3 refer). The heart of the Wesfarmers–Marubeni Project proposal is the development of a world scale sugar industry (Section 1.2 refers).

Development of irrigation infrastructure would be an integral component of the proposed development. The Water Corporation of Western Australian (Water Corporation) is investigating the feasibility of development of the irrigation infrastructure, in parallel with the feasibility study being conducted by Wesfarmers–Marubeni (Section 1.3.4 refers).

Due to the importance of water related issues to the environment, and due to the integrated nature of the proposed sugar industry and the irrigation infrastructure, Wesfarmers–Marubeni and the Water Corporation have agreed to have a single and joint environmental assessment undertaken of the proposed development.

1.2 THE PROJECT

1.2.1 Project overview

The scope of this report involves the potential development of an export-based raw-sugar industry—the Project. Australia is currently one of the world’s largest exporters of raw sugar, and at full development the Project would contribute an additional indicative 10% to the current national exports of raw sugar.

Key features of the Project are:

- development of approximately 32,000 hectares of irrigable land in the Project Area consisting of sugarcane plantation development by Wesfarmers–Marubeni of approximately 29,000 ha and the sale of approximately 3,000 hectares of land by Wesfarmers–Marubeni to independent farmers on an unconditional basis with respect to the types of crops that may be grown. The commitments made in this report would also apply to this land;
- the development of a raw-sugar mill by Wesfarmers–Marubeni with a capacity of approximately 400,000 t/a of raw sugar and 160,000 t/a of molasses;
- the development by Wesfarmers–Marubeni of raw sugar and molasses storage and handling facilities at Wyndham port;

- the development of irrigation, drainage and flood protection infrastructure by the Water Corporation;
- establishment and on-going management of over 40,000 ha of additional land in the Project Area for conservation purposes.

The Project is described in more detail in Chapter 3.

Following development, the Project Area (Figure 1.1) would include land developed for farms and associated infrastructure, and other land managed for conservation. Farm areas would be developed on the heavy clay soils (black soils), while the land managed for conservation would include those areas that contain flora and fauna of conservation significance and other areas that provide a buffer between the farm areas and surrounding land uses. Table 1.1 provides a summary of the proposed land uses within the Project Area, including proportions within Western Australia and the Northern Territory.

Table 1.1 Proposed land uses within the Project Area

Land use	Location		Total
	Western Australia	Northern Territory	
Farm area (ha)*	16,500	15,290	31,790
Infrastructure (ha)*	1,790	1,220	3,010
Conservation (ha)*	16,610	24,350	40,960
Total	34,900	40,860	75,760

* Rounded to nearest 10 ha.

At this time, it is anticipated that farm development would be substantially complete by 2003 and cane harvested from all three plains by 2005.

Raw sugar and molasses would be trucked from the mill to storage facilities at Wyndham. Sugar and molasses would be exported, predominantly to Asia, in 20,000 t vessels.

In the start-up phase and early years of operation Wesfarmers–Marubeni would own and operate the sugarcane plantation business. However, over time and as supply of cane with the desired quality attributes becomes well proven, the corporate farm may be gradually subdivided and sold down to independent sugarcane growers.

1.2.2 Products and markets

Sugar: use and markets

Sugar is used extensively as a natural sweetener in food and beverages. Molasses, a by-product of sugar production, is used predominately for the production of alcohol (ethanol) by fermentation and food additives such as mono-sodium glutamate.

World sugar demand in 1998 was approximately 121 Mt, with approximately 38% of this demand arising from Asia.

From 1973 to 1994, the growth in world sugar consumption was 1.98% pa (International Sugar Organization 1994), and over the same period the average annual world per capita consumption was approximately 20 kg. From 1955 to 1994, the annual average growth rate of sugar consumption exceeded the world population growth rate.

Sugar is traded in two forms: raw (principally in bulk) and white (principally in bags). World trade in 1998 was about 35 Mt, with approximately equal amounts of raw and white sugar.

The world sugar trade is heavily regulated. Mechanisms utilised to protect domestic sugar industries include preferential import quotas in the United States and the European Union, import tariffs and export quotas. In recent years, with the break-up of the Soviet Union and the collapse of communism in Eastern Europe, the quantity of sugar entering the world 'free trade' market has risen. The proportion of sugar entering the world free trade market is expected to increase as a consequence of further increases in trade liberalisation.

Raw-sugar prices have traditionally been volatile, but have stabilised somewhat over recent years (Figure 1.2). Raw sugar prices maintained their real value during the early 1990s.

The oil crises and high inflation of the early 1970s and 1980s contributed to the price peaks in those periods, whilst the relative stability following the early 1980s has been attributed to a higher proportion of freely traded raw sugar and an increased volume of futures trading.

Sugar industry

World sugar production in 1998 was approximately 130 Mt. Production growth (Table 1.2) over the last five years, of around 20 Mt, has been predominantly from Thailand, Brazil and India.

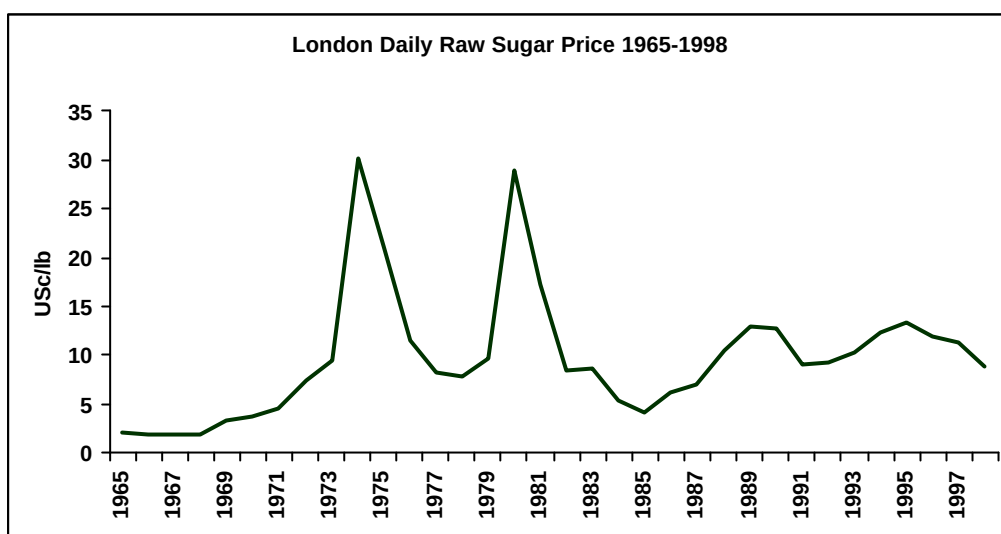
Table 1.2 Regional world sugar production

Region	1994 (Mt)	1998 (Mt)
Africa	7.20	9.10
Central America	11.25	12.90
North America	7.09	7.26
South America	17.95	25.58
Asia	32.89	37.58
Oceania	5.80	5.41
Eastern Europe	8.76	8.17
Western Europe	18.64	20.91
Total	109.58	126.91

Source: LMC International Ltd (1999)

Sugar is produced from sugarcane, predominately in the southern hemisphere, and sugarbeet, predominately in the northern hemisphere. Sugar production is constrained by climate and is of a seasonal nature, whilst demand for sugar is relatively steady throughout the year. As a consequence, inventories of sugar are necessary to satisfy the steady demand. The world sugar inventory at the end of 1998 was estimated at 60 Mt (source: LMC International Ltd, 1999).

Figure 1.2 World sugar prices



Source: LMC International Ltd (1999)

Other crops

Crops other than sugarcane may be grown within the Project Area, on land owned and managed by independent farmers. Therefore, it is possible that any of the range of broad-acre crops currently being grown on the ORIA (Section 2.1 refers) could be grown on the Project Area.

1.3 THE PROPONENTS

1.3.1 Co-proponents

As outlined in Section 1.1.4, Wesfarmers–Marubeni and the Water Corporation have elected to be Co-proponents of the environmental assessment of the proposed development.

The responsibilities of the respective co-proponents for the Project are as follows:

- Wesfarmers–Marubeni: farm development, field and crop preparation and management, access roads, power and communications infrastructure, the raw-sugar mill, and storage and loading facilities at Wyndham Port;
- the Water Corporation: development and management of the irrigation water supply, drainage and flood protection infrastructure.

The rationale for Wesfarmers–Marubeni and the Water Corporation electing to be co-proponents of this environmental assessment lies in the integrated nature the proposed industry and proposed irrigation infrastructure, and the importance that water related issues would have to the environment. The single and joint assessment does, however, allow the environmental management responsibilities of each of the proponents to be separately identified and allocated.

1.3.2 Wesfarmers

Wesfarmers Sugar Company Pty Ltd is a wholly-owned subsidiary of Wesfarmers Limited.

Wesfarmers Limited is a major diversified Australian public company with current net assets in excess of \$1 billion and market capitalisation of over \$3 billion.

The company's origin in 1914 as a Western Australian farmers' cooperative determined its early focus on the provision of services and merchandise to the rural community. While maintaining this focus, Wesfarmers Limited has undertaken a diversification programme which has resulted in a greatly broadened business and geographical base.

Today, Wesfarmers Limited is a diversified corporation with interests in fertilisers and chemicals manufacture and marketing; gas processing and distribution; coal mining and production; building materials, hardware and forest products; and rural and country services. The rural business interests include merchandising and rural agency activities, transport and insurance services.

Wesfarmers Limited has exhibited the capability to develop and operate projects in a range of new industries and under a range of technical and economic conditions. In many of its project developments Wesfarmers Limited has played an integral role in development, design and project delivery, and in doing so has exhibited the in-house technical capability to deliver and operate complex projects. Successful environmental management has been fundamental to project delivery.

Wesfarmers Limited has significant exposure to primary production through its tree-farming operations in the south-west of Western Australia. The company has developed approximately 40,000 ha of *Eucalyptus globulus* plantations since 1981, the current development rate being about 5,000 ha/a. Expertise for the development of tree plantations has been developed in-house to a point where the company's skills are recognised by independent operators, and its services are contracted out to private plantation developers around Australia.

Wesfarmers Limited is familiar with the unique conditions that apply to development and operations of businesses in the Kimberley region. The harsh climatic conditions and geographic isolation demand perseverance and patience in the operation of local businesses. Wesfarmers Limited, through a 100% subsidiary company, Wesfarmers Transport, has successfully provided transportation services in the Kimberley for many years. More recently, Wesfarmers Transport has developed a sugarcane transportation business servicing ORIA Stage 1 and has established a regional office in Kununurra.

Wesfarmers Limited has a strong commitment to responsible environmental management throughout all company operations. Of the five publically stated group objectives of Wesfarmers Limited, two refer specifically to environmental objectives as follows:

“Wesfarmers aims to:

- respond to the attitudes and expectations of the communities in which it operates and place strong emphasis on achieving sustainable development and protection of the environment;
- provide a fulfilling and safe working environment for employees, to reward good performance and to provide opportunities for advancement.”

In January 1999, Wesfarmers Limited released a comprehensive and publically available Environment, Health and Safety Report, which documents performance from a number of the company's operating businesses for 1997/98. It is envisaged that the Report will be prepared on an annual basis in the future.

1.3.3 Marubeni

Marubeni is one of Japan's leading general trading companies. Marubeni operations encompass domestic, import, export and offshore trade, and investment activities, and range from the development of natural resources to the retail marketing of finished products. The company conducts operations through a worldwide business network composed of nearly 200 representative offices and more than 600 affiliated companies in eighty-four countries. Marubeni's trading transactions in 1998-99 were in excess of \$US100 billion.

Through its Agri-Marine Products Group, Marubeni is a major world trader of cereals, oilseeds, feed and food materials, foodstuffs and beverages. As part of this business Marubeni has had a long history of sugar trading and currently handles approximately 700,000 t/a of sugar. The Marubeni Sugar Division has offices in New York, London, Bangkok, Tokyo, Manila and São Paulo from which trade is conducted in raw sugar, refined sugar and molasses.

The Machinery Division of Marubeni is active in the development of a wide range of chemical, industrial and power generation plants throughout the world. As part of these operations, Marubeni has played a prominent role in the development of sugar mills and sugar refineries in the Philippines, Venezuela, Indonesia and Morocco.

Marubeni Corporation (Tokyo) has ISO 14001 accreditation for Environmental Management System Standards, in relation to procurement, delivery of services and investments.

1.3.4 The Water Corporation

The Water Corporation was established as a body corporate under the provisions of the *Water Corporation Act 1995* and is the principal water utility for Western Australia. Water, wastewater, drainage and irrigation services are provided under this Act and other legislation controlling the water industry.

The principal functions of the Water Corporation are:

- to acquire, store, treat, distribute, market and otherwise supply water for any purpose;
- to collect, store, treat, market and dispose of wastewater and surplus water;
- to undertake, maintain and operate any works, system, facilities, apparatus or equipment required for any of these purposes;
- to develop and turn to account any technology, software or other intellectual property that relates to any of these functions;
- to manufacture and market any product or by-product that relates to any of these functions;
- to use expertise and resources to provide consultative, advisory or other services for profit.

The Water Corporation has an asset base of \$8.5 billion and provides a total water service to a population of over 1.7 million people in urban and rural communities across the 2.5 million km² of Western Australia. In providing these services, the Water Corporation employs over 2,000 people on a full-time basis.

In the north-west region, the Water Corporation supplied 23,800 ML of water to over 24,000 properties during 1997–98. In ORIA Stage 1 approximately 260,000ML were supplied for irrigation.

The Water Corporation has undertaken developments that have a strong environmental emphasis such as Waterlink projects at Kwinana and Kalgoorlie, sludge digesters at the Woodman Point Wastewater Treatment Plant, and an oil-from-sludge digester at the Subiaco Wastewater Treatment Plant. The Water Corporation's commitment to the environment was elaborated when it launched its Environmental Policy in September 1997.

1.4 THE APPROVALS PROCESS

1.4.1 Western Australia and the Northern Territory regulatory framework

A Memorandum of Understanding was signed on 19 April 1995 by the Chief Minister of the Northern Territory and the Premier of Western Australia in response to the desire of both their Governments to complete the originally envisaged Ord River Irrigation Scheme. The Memorandum of Understanding provides a framework for sharing information from studies into the scheme and for planning by agencies of the respective Governments and by the private sector.

The Memorandum of Understanding is not intended to create legal relations between the two Governments; neither does it remove the need for compliance with legal requirements by proponents of the development. It is also recognised by both Governments that the Memorandum of Understanding will require further negotiation when and if development proceeds.

The development and operation of the Project must comply with all relevant State, Territory and Commonwealth legislation. Table 1.3 provides a listing of the legislation, treaties and national agreements of particular relevance to the Project. The legislation requires the issuing of licences or approvals prior to the commencement of construction or operation.

1.4.2 The environmental impact assessment procedure

The Governments of Western Australia and the Northern Territory have agreed that the Project should be jointly assessed utilising the Western Australian environmental impact assessment process of the *Environmental Protection Act 1986*. This process is shown diagrammatically in Figure 1.3.

In 1996, the Department for Resources Development (DRD) referred to the Western Australian Environmental Protection Authority (EPA) a proposal to develop the Project Area and were notified that a Public Environmental Review was the appropriate level of assessment. A draft of the Public Environmental Review was prepared, but it was never published.

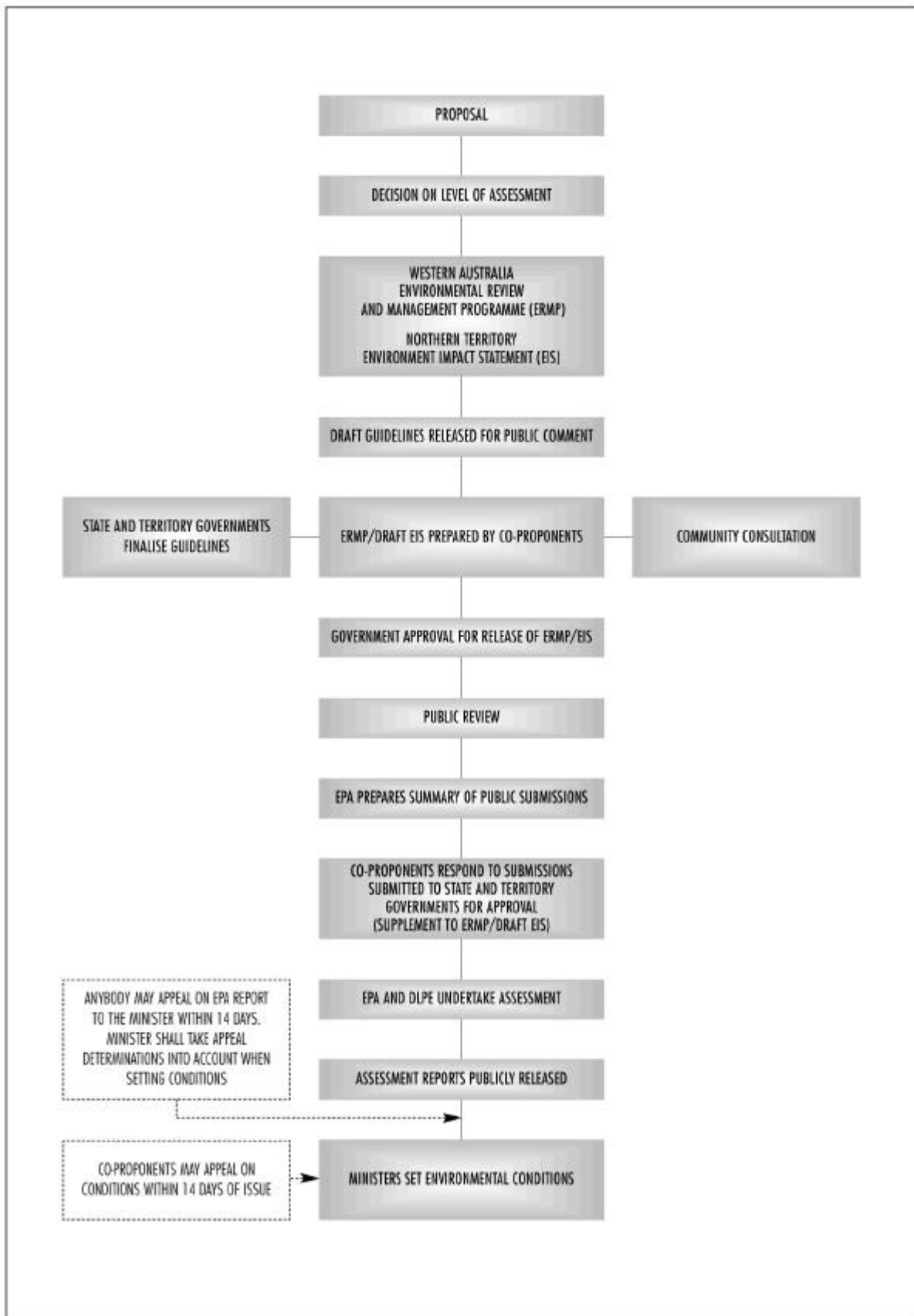


Figure 1.3 Environmental Impact Assessment Process Flow Chart

DRD withdrew its referral when the environmental impact assessment process commenced again with a referral of the Project by Wesfarmers–Marubeni and the Water Corporation to the EPA in September 1998. Following consideration of the referral, the Governments agreed that the assessment should be an Environmental Review and Management Programme (ERMP) in Western Australia and an Environmental Impact Statement (EIS) in the Northern Territory.

A draft set of guidelines for this ERMP/draft EIS was advertised for public comment and remained open for public comment for a period of three weeks until 14 May 1999. The finalised guidelines, released on 19 July 1999, which incorporate changes resulting from the assessment of public comments, are contained in Appendix A.

Table 1.3 Relevant legislation, treaties and agreements

Western Australian legislation	Northern Territory legislation	Commonwealth legislation, international and national agreements or treaties
<i>Aboriginal Heritage Act 1972</i>	<i>Aboriginal Land Act 1992</i>	<i>Aboriginal and Torres Strait Islander Heritage Protection Act 1984</i>
<i>Aerial Spraying Control Act 1966</i>	<i>Aboriginal Land Rights (Northern Territory) Act 1976</i>	<i>Australian Heritage Commission Act 1985</i>
<i>Agricultural and Veterinary Chemicals (Western Australia) Act 1995</i>	<i>Agricultural and Veterinary Chemicals (Northern Territory) Act 1995</i>	<i>Environmental Protection (Impact of proposals) Act 1974</i>
<i>Agriculture Act 1988</i>	<i>Environmental Assessment Act 1994</i>	<i>National Parks and Wildlife Conservation Act 1975</i>
<i>Conservation and Land Management Act 1984</i>	<i>Environmental Offences and Penalties Act 1996</i>	<i>National Environment Protection Council Act 1994</i>
<i>Environmental Protection Act 1986</i>	<i>Control of Roads Act 1996</i>	<i>National Environment Protection Measures (Implementation) Act 1998</i>
<i>Fisheries Resources Management Act 1994</i>	<i>Fisheries Act 1996</i>	<i>Environment Protection and Biodiversity Conservation Act 1999</i>
<i>Health Act 1911</i>	<i>Heritage Conservation Act 1996</i>	<i>Endangered Species Protection Act 1992</i>
<i>Heritage of Western Australia Act 1990</i>	<i>Lands Acquisition Act 1996</i>	<i>Native Title Act 1993</i>
<i>Land Administration Act 1997</i>	<i>Local Government Act 1996</i>	<i>Convention on Biological Diversity National Strategy for Ecologically Sustainable Development</i>
<i>Local Government Act 1995</i>	<i>Northern Territory Aboriginal Sacred Sites Act 1995</i>	<i>Convention on Wetlands of International Importance especially on Water Fowl Habitat (1975) (The Ramsar Convention)</i>
<i>Main Roads Act 1930</i>	<i>Noxious Weeds Act 1994</i>	<i>China–Australia Migratory Bird Agreement (CAMBA), 1988</i>
<i>Rights in Water and Irrigation Act 1914</i>	<i>Parks and Wildlife Commission Act 1995</i>	<i>Japan–Australia Migratory Bird Agreement (JAMBA), 1981</i>
<i>Soil and Land Conservation Act 1945</i>	<i>Pastoral Land Act 1996</i>	
<i>Town Planning and Development Act 1985</i>	<i>Plant Diseases Control Act 1996</i>	
<i>Water Agencies (Powers) Act 1984</i>	<i>Public Health Act 1995</i>	
<i>Water Corporation Act 1995</i>	<i>Soil Conservation and Land Utilization Act 1995</i>	
<i>Water and Rivers Commission Act 1995</i>	<i>Territory Parks & Wildlife Conservation Act 1996</i>	
<i>Water Services Coordination Act 1995</i>	<i>Water Act 1996</i>	
<i>Waterways Conservation Act 1976</i>		
<i>Wildlife Conservation Act 1950</i>		

The ERMP/draft EIS is available for comment by the public and by Government departments and agencies for a period of ten weeks. During this time members of the public are invited to forward comments on any aspect of the proposal to the EPA.

The EPA will prepare a summary of the public submissions for comment by the Wesfarmers–Marubeni and the Water Corporation. Following receipt of these comments in the form of a Supplement to the ERMP/draft EIS the relevant State and Territory Government departments and agencies will assess the proposal and publish the results in assessment reports.

In Western Australia, the ERMP and subsequent EPA advice will form the legal basis for the Western Australian Minister for the Environment’s decision in relation to the proposal. Any approval to implement the proposal would be subject to enforceable environmental conditions, which would also include commitments given by the Wesfarmers–Marubeni and the Water Corporation. In the Northern Territory, the EIS will form the basis for recommendations that the Minister for Lands, Planning and Environment may make to the Northern Territory Cabinet on the proposal.

It should be noted that construction of the Project would not commence until the environmental impact assessment process is complete and the ministerial approvals and conditions have been obtained. Planning and design activities can, however, proceed independently of the environmental impact assessment process.

1.5 CONSEQUENCES OF NOT PROCEEDING WITH THE PROJECT

If the Project does not proceed, there would be some consequences (benefits and disbenefits) for the environment. There would also be consequences for the sugar and molasses industry and for the regional, Western Australian and national economies. These are summarised below.

1.5.1 Environmental consequences of not proceeding

All projects result in some impact to the environment. It is the role of project planners, developers and regulators to ensure that no significant adverse environmental impacts occur, and that any residual impacts are managed and minimised.

This Project involves the use of existing and currently underutilised water source and distribution facilities at Lake Argyle and Lake Kununurra. Hence, the potential for environmental disturbance is less than that for an irrigation project requiring the further damming of rivers. Nevertheless, there would be some environmental benefits, both real and perceived, associated with not proceeding with the Project, and these are outlined below. These benefits should be considered against the significant economic benefits accruing from the Project.

Clearing of vegetation

One of the primary consequences of the Project not proceeding is that some 36,400 ha of existing vegetation, predominantly grassland with scattered low trees found on the black soil plains, would not be cleared. However, the project development plan contains features to mitigate the consequences of vegetation clearing and to ensure maintenance of biodiversity in the region. These features include:

- the provision of dedicated conservation areas within the Project Area. These conservation areas contain vegetation assemblages that are representative of those found in the Project Area, as well as flora and fauna identified as having regional conservation significance;
- the maintenance of riparian vegetation along watercourses and permanent waterbodies;
- the provision of corridors for the movement of fauna, between areas set aside for conservation and the surrounding undeveloped country;
- the active management of all conservation areas and, wherever possible, infrastructure corridors for the purpose of ensuring ecologically sustainable development and maintenance of biodiversity. As a minimum, management of the areas would include removal of stock, control of access, monitoring and control for weeds and introduced species, and monitoring of environmental and ecological parameters.

The Project's Environmental Management Plan (EMP) would contain the detailed provisions to manage all of the Project Area, including areas not developed. It should be noted that the Project Area and the surrounding countryside are currently used for cattle grazing and that no formal management measures currently exist for the protection of the flora and fauna in these areas.

Another consequence of the Project not proceeding is that an opportunity may be lost to add to the conservation estate of Western Australia and the Northern Territory. This opportunity would arise land excisement required from existing pastoral leases, to enable the proposed development to occur. This opportunity could be a significant contribution to fulfilling one of the principles of the National Strategy for the Conservation of Australia's Biological Diversity (Commonwealth of Australia 1996)—the establishment of a comprehensive, representative and adequate system of ecologically viable protected areas integrated with sympathetic management of all other areas, including agricultural and other resource production systems.

The ongoing management proposed for the Project's conservation areas would include research focussed at improving environmental management systems for these areas. The outcomes of this research should be applicable to the broader region, however the research would not occur if the Project does not proceed.

Receiving waters

The Project Area drains predominantly to the Keep River, and to a lesser extent to Sandy Creek, both located in the Northern Territory. Apart from limited development associated with pastoral activities, the catchments of these watercourses are currently undeveloped.

The project development plan recognises the need to preserve the water quality and hydrology of the receiving waters to the maximum extent possible. In particular, all farm blocks would be developed with irrigation tailwater return systems in order to virtually eliminate discharges from farms during the dry season. First-flush stormwater would also be retained by these systems. Stormwater discharges during the wet season would be diluted by flows from surrounding catchments, sufficient to reduce nutrient and pesticide levels to levels consistent with the maintenance of existing environmental values.

Groundwater

Groundwater in the Project Area generally exists at depths greater than 10 m below surface and range in quality from fresh to saline (50,000 mg/L TDS). Development for irrigated farmland would alter the existing equilibria, leading to a rise in groundwater levels. It is known in extreme cases that excessive rises in groundwater levels can lead to water logging and salinisation.

The project development plan includes management measures designed to avoid the adverse impacts outlined above. These management measures include:

- the avoidance of areas shown to be susceptible to rapid groundwater rise;
- the adoption of irrigation water regimes that match plant water requirements, thereby minimising overwatering and accessions to groundwater;
- the implementation of a comprehensive monitoring programme designed to provide early detection of potential problems;
- the implementation where necessary of remediation strategies, including groundwater recovery, using bores or subsurface drains, or a combination of both.

There is a high level of confidence that the above management measures would be successful. However, not proceeding with the Project would prevent the potential risks from arising.

Secondary impacts

There are a number of secondary impacts that would be avoided if the Project did not proceed, including:

- increased visitation of conservation areas, pastoral leases, and areas of significance to Aboriginal people, brought about by increased population and improved regional road networks;
- increases in mosquito-borne infections resulting from an increased population residing in the area.

This report outlines the measures proposed to manage these issues during operations, although both issues are outside the direct responsibility of the co-proponents.

1.5.2 The sugar market

At a potential production rate of 400,000 t/a of raw sugar, the proposed industry would be a relatively large individual producer. However, this output would still only represent a small percentage, about 0.3%, of current world production. As outlined in Section 1.2.2, much of the current sugar production is tied to consumers and a smaller amount, about 35 Mt/a, is traded on the free market. Project production would, therefore, only represent about 1% of the annual trade in sugar.

There are a number of other large projects at varying stages of development throughout the world, many situated in developing countries where environmental legislation and management is not as sophisticated as in Australia. Given that sugar demand growth is maintained, sugar production foregone from the Project would conceivably be replaced by the expansion of existing projects elsewhere, or by the development of new projects.

There are no known alternative sugar projects in Australia at this time of the scale of the proposed development. It is therefore likely that replacement production would be substantially sourced overseas, and the benefits of development lost to Australia.

1.5.3 The State and national economies

The estimated benefits for the regional economy from the Project are substantial and include:

- the creation of up to 650 new jobs at Kununurra during the construction phase;
- the creation of around 800 new permanent jobs during production, including 550 direct jobs at Kununurra;
- an increase in receipts by the State of Western Australia from water sales from the Project during production;
- improved regional infrastructure;
- increased tax revenue for the State of Western Australia, the Northern Territory and the Commonwealth;
- an increase in annual revenue from the export of raw sugar and molasses and a consequent positive annual impact on Australia's balance of trade during production.

Should the Project not proceed, these benefits could be lost to the regional, State and Australian economies, because there are no known alternative developments with the same potential for investment in the region, particularly in a long-term context. In the short to medium term, the Australian economy would lose the opportunity to export a valuable commodity into world markets.

1.6 SCOPE AND STRUCTURE OF THE REPORT

1.6.1 Scope

The scope of this ERMP/draft EIS covers the environmental implications of the Project in response to the ERMP/draft EIS guidelines (Appendix A) issued by the State and Territory Governments.

The ERMP/draft EIS does not visit issues associated with the construction and operation of the existing irrigation scheme (ORIA Stage 1), except to learn from these previous experiences for the purpose of establishing environmental best-practice performance in relation to the proposed development. The ERMP/draft EIS also does not include issues associated with the water resource allocation from the Ord River. Section 5.2 outlines the assessment process being adopted by the State for this issue.

1.6.2 Structure

Two key considerations have shaped the structure of this ERMP/draft EIS: the need to describe the scale and physical characteristics of the Project in the most effective way, and the need to examine those environmental factors that have been identified in the ERMP/draft EIS guidelines and by the co-proponents as being the most relevant in assessing the environmental effects of the proposal.

The existing developments in the ORIA are described in Chapter 2. The physical elements of the Project are described in Chapter 3. Subsequent chapters (Chapters 4 to 15) describe the effects of the Project on the existing environment, with environmental aspects grouped according to their relationship to major elements of the Project (Table 1.4). Chapter 16 describes the environmental management framework proposed for the Project, while a summary of the commitments made in this ERMP/draft EIS is provided in Chapter 17.

Table 1.4 Report structure

Major project element	Environmental considerations	Chapter
Project description	• Existing operations—general	2
	• Future operations—general	3
Biophysical environment	• Physical environment	4
	• Surface hydrology	5
	• Groundwater	6
	• Terrestrial vegetation and flora	7
	• Terrestrial habitats and fauna	8
	• Aquatic flora, fauna and habitats	9
	• Conservation strategy	10
	• Land use	11
Social environment	• Issues specific to Miriuwung and Gajerrong people	12
	• Air quality	13
	• Public health	14
	• Community issues	15
Environmental management	• Management framework	16
	• Summary of environmental commitments	17

The individual chapters discuss the present environment, the potential impact of the Project, and the proposed environmental controls, management systems and procedures. Where appropriate, the assessment method is also described.

Appendix A presents the ERMP/draft EIS guidelines as finalised by the State and Territory Governments following public comment.

Of necessity, this ERMP/draft EIS contains a significant number of technical terms. As these may not be familiar to readers, a glossary has been included as Appendix B. Technical abbreviations used in the document are contained in Appendix C, while references are brought together as Appendix D. The agencies consulted during preparation of this document are listed in Appendix E. Appendix F lists members of the study team. The technical appendices relating to specific chapters are bound separately.

2 The existing Ord River Irrigation Area

This chapter describes the existing development of ORIA Stage 1 by providing background information on the crops grown and the management responsibilities of the major stakeholders in the scheme. A brief discussion of the environmental issues of significance is provided, together with a discussion on how these issues are currently being managed. The chapter focuses on the implications for the Project—in essence, what can be learned from the existing development to minimise environmental impacts from the Project.

2.1 CROPS AND PRODUCTS

The existing ORIA Stage 1 comprises a cropped area of approximately 11,500 ha, and supports a broad range of agricultural production. In 1997–98, agricultural production had an estimated value of over \$56 million, as shown in Table 2.1.

Table 2.1 ORIA Stage 1—value of production 1997–98

Crop	Value 1997–98 (\$)
Sugarcane	17,334,345 *
Rockmelons	7,912,943
Bananas	4,465,124
Honeydew melons	4,383,855
Other horticulture**	3,470,723
Butternuts	3,076,961
Watermelons	2,856,209
Jarrahdale	2,065,267
Jap pumpkin	1,849,529
Leucaena/pasture	1,692,338
Sorghum	1,559,889
Cotton	1,508,716 *
Chick pea	945,000
Maize	909,800
Hay/dairying	794,800
Mangoes	714,872
Sunflower	411,000
Miscellaneous field crops	352,160
Miscellaneous hybrid seeds	180,000
Soy beans	92,799
Total	56,576,330

* Includes revenue from sugar-milling and cotton-ginning operations.

** Includes citrus, squash, zucchini, cucumbers, papaya, herbs, asparagus, jack fruit, okra, carambola, egg plant, sweetcorn, beans, nursery and seedless watermelon.

Source: Agriculture Western Australia 1998.

Historically a range of different crops has been trialled and grown commercially in ORIA Stage 1.

From the 1960s to the early 1970s, the principal crop grown was cotton. By 1970–71, cotton was grown on 3,600 ha of the 5,400 ha under cultivation, with grain sorghum and hay being the other recorded commercial crops.

By 1980, cotton was no longer grown due to the high susceptibility of the crop to local pest insects, and the area under cultivation had decreased to 4,800 ha. The greater part of the cropped area in 1980 was dedicated to sorghum, sunflower and hay. Other crops included rice, mung bean, seed crops and melons.

By 1990–91, the cropped area had decreased further to 4,300 ha. Rice and mung bean were no longer grown, and new crops included soy beans, maize, chick pea and peanuts. By this stage, horticulture had become an established industry, dominated by mangoes, bananas, and cucurbits (melons and pumpkins). Irrigated pasture, including leucaena, had become established to serve the local pastoral industry.

By 1996, a raw-sugar industry had been established in ORIA Stage 1 and in 1996–97, revenue generated by the local sugar industry was about \$17 million, or 27% of the total value of agricultural production. By 1998, an area of 3,800 ha of sugarcane was grown in ORIA Stage 1, and processed into 51,173 t of raw sugar.

The advent of transgenic cotton resulted in trial commercial plantings of 250 ha in 1996–97, and in 1998 a pilot cotton gin was commissioned to process the seed cotton.

An estimate of the area under cultivation by crop type over the period 1970–71 to 1997–98 is provided in Table 2.2.

Table 2.2 Estimated crop areas in ORIA Stage 1 (ha)

Crop	1970–71	1980–81	1990–91	1994–95	1996–97	1997–98
Sugarcane	–	–	–	2,900	3,793	3,800
Pasture crops and dairying	553	735	735	1,800	1,775	1,791
Chick pea	–	–	730	610	749	725
Sorghum	1,229	1,506	461	1,429	556	653
Rockmelon	–	26	366	477	897	615
Miscellaneous	–	125	25	675	387	567
Maize	–	–	880	560	512	544
Pumpkins	–	–	–	253	851	510
Cotton	3,617	–	–	–	250	447
Watermelon	–	26	110	320	554	375
Honeydew melons	–	–	–	–	–	300
Sunflower	–	1,772	500	385	138	137
Bananas	–	–	135	132	131	120
Mangoes	–	–	80	200	276	295
Culinary beans	–	–	–	75	591	–
Zucchini/cucumber	–	–	–	–	72	–
Soy bean	–	–	310	–	30	–
Rice	–	630	–	–	–	–
Sandalwood	–	–	–	–	–	240
Total	5,399	4,820	4,332	9,816	11,562	11,119*

* Land ploughed out due to aphid and mosaic virus infection not included in total.

Sources: Agriculture Western Australia 1998 and Governments of Western Australia and Northern Territory 1996.

The diversity of crop types grown in ORIA Stage 1 is attributable in part to the local variation in soil types. Broad-acre crops, such as sugarcane, cotton and leucaena, and some horticultural crops such as rockmelons, watermelons and pumpkins, are cultivated on black

cracking clays utilising furrow irrigation. Other crops, such as bananas and tree crops, are grown mainly on lighter textured levee soils utilising sprinkler or drip irrigation.

Post-harvest activities in ORIA Stage 1 include the milling of sugarcane, ginning of cotton and packaging of horticultural produce.

2.2 MANAGEMENT RESPONSIBILITIES

There are a number of individuals, grower groups, businesses and Government agencies with responsibility for various management functions in ORIA Stage 1, which impact the local environment. These responsibilities are summarised in the following sections.

2.2.1 Farmers

The majority of farms in ORIA Stage 1 are managed by owner/operators. Corporate farming currently utilises an area of approximately 3,200 ha, and is involved in the production of hybrid seeds, leucaena, sandalwood and host trees, cotton and mangoes.

The farmers in ORIA Stage 1 have the primary responsibility for the environmental management of land under their care. Farmers are responsible for the type and quantity of crops grown, and also for the application rates of water, fertilisers, herbicides and pesticides.

Farmers must comply with a range of State and Commonwealth legislation related to environmental issues, including:

- agricultural statutes such as the *Aerial Spraying Control Act 1996* and the *Soil and Land Conservation Act 1945*;
- land statutes such as the *Land Administration Act 1997*;
- planning and regional development statutes, such as the *Town Planning and Development Act 1985* and the *Local Government Act 1995*;
- Aboriginal and cultural heritage statutes such as the *Aboriginal Heritage Act 1972* and the *Native Title Act 1993*;
- environmental protection statutes such as the *Environmental Protection Act 1986*.

The farmers of ORIA Stage 1 have formed a range of industry groups, to promote good agriculture management techniques, market a range of produce and address environmental issues including:

- Ord River District Co-operative
- Ord Land and Water
- Kununurra Horticulture Producers Association
- Ord Mango Growers Association
- Leucaena Growers Association
- Ord Cucurbit Growers Group
- Ord Cane Growers Association
- Ord Sugar Industry Board

- Ord River Grain Pool.

The activities of the Ord River District Co-operative and the Ord Land and Water Management Plan Steering Committee are summarised in Sections 2.2.2 and 2.2.3 respectively.

2.2.2 Ord River District Co-operative

The Ord River District Co-operative was established in 1963 for the purposes of processing and marketing cotton. Over the years, it has become involved in the provision of supplies, processing, marketing and support services for a diverse range of crops and agricultural activities in ORIA Stage 1. The Ord River District Co-operative, now with approximately 110 shareholders and a seven-member Board, has an economic interest in the following:

- the local sugar mill
- port storage and handling facilities at Wyndham
- the local distribution of packaging products
- an aerial spraying business
- a local pilot cotton gin.

The Ord River District Co-operative is one of the preferred proponents investigating the feasibility of developing approximately 800 ha of irrigable land adjacent to ORIA Stage 1, known as 'Green Location', and is the manager of the operations of the port at Wyndham.

With respect to environmental issues, the Ord River District Co-operative is a supplier of fertilisers and agricultural advisory services to farmers in ORIA Stage 1, and its Board members are actively involved in a range of local industry, community and environmental groups. It also has quality standard certification for agricultural chemical storage and retailing, and manages an insect-scouting service as an agent of the Ord River Grain Pool.

2.2.3 Land and Water Management Plan Steering Committee

The initiative for preparing a Land and Water Management Plan came from local farmers in 1996 as a means to address the environmental issues relevant to ORIA Stage 1 at that time. Coordinators for the preparation of the Plan were employed in May 1997 and a Steering Committee was established in March 1998 following a public forum.

The Steering Committee has eight members elected from different sectors of the community: three members represent farming interests; one member represents conservation interests; one member represents business interests; one member represents river interests; there is ex-officio representation by the District Team Leader from Agriculture Western Australia (AGWEST); and one member is a Director from the Ord Irrigation Co-operative (Section 2.2.8 refers).

To date, the Steering Committee has convened a number of discussion forums, all well attended by a range of environmental stakeholders, and it is actively engaged in community consultation in ORIA Stage 1, with respect to the production of a Land and Water Management Plan (Section 2.3.5 refers).

2.2.4 Ord Development Council

The Ord Development Council (ODC) was established in 1991 by the Minister of Primary Industry with the objective of facilitating further agricultural development in the Ord River district. The council comprises twelve representatives from local industry and the community, and is administered by a full-time executive officer.

The ODC plays a pivotal role in the facilitation of local agricultural development.

2.2.5 Water and Rivers Commission

The Water and Rivers Commission, established under the *Water and Rivers Commission Act 1995*, is responsible for administering the *Rights in Water and Irrigation Act 1914*. The Act contains provisions relating to the conservation and utilisation of natural waters in Western Australia, and the Water and Rivers Commission is empowered to manage those waters.

Responsibilities of the Commission include the quantification of water that may be diverted from river systems and groundwater aquifers, a process known as water allocation planning. One of the aims of water allocation plans is to ensure that diversion of any natural waters does not compromise the integrity of water-dependent ecosystems. Allocation plans are implemented through licences, issued by the Commission, which clearly define the allowable water use and any relevant conditions necessary for good management of natural water resources.

Water used for the purposes of irrigation and agricultural processing in ORIA Stage 1 is subject to a licence issued by the Water and Rivers Commission. In the case of ORIA Stage 1, the licensee is the bulk-water provider, the Water Corporation (Section 2.2.7 refers).

To accommodate proposed ORIA Stage 2 developments, including the potential supply of irrigation water to the Project Area, the Commission has prepared a Draft Interim Water Allocation Plan for review by the EPA and the public. The Draft Interim Water Allocation Plan includes water allocations for ORIA Stage 1, ORIA Stage 2 (including the Project Area) and water-dependent ecosystems. The Plan includes the basis for a licensing system for all potential water users and is discussed further in Chapter 5.

2.2.6 Office of Water Regulation

The Office of Water Regulation was established to administer the *Water Services Coordination Act 1995*. Responsibilities of the Office include:

- regulation and licensing of water services provision in Western Australia;
- coordination of water services policy and provision of advice to the Minister for Water Resources.

Under the Act, any water service provider in Western Australia must have an operating licence, issued and administered by the Office of Water Regulation. Licences apply to the provision of water supply, sewerage, irrigation and drainage services.

Licensees must satisfy a number of conditions in relation to the provision of water services, including water quality and customer service. Compliance with licence conditions is monitored through regular audits performed by licensees and external audits performed by

the Office of Water Regulation. Licences are vested with the owner of the water assets, and are not transferable.

In the case of ORIA Stage 1, the irrigation infrastructure is owned by the Water Corporation (Section 2.2.7 refers). The Water Corporation holds an operating licence from the Office of Water Regulation for all of its water provision activities throughout Western Australia and that licence includes conditions relating to the provision of water services in ORIA Stage 1.

2.2.7 The Water Corporation

The Water Corporation is the licensed provider of water services to the town of Kununurra, and to farms and industry in ORIA Stage 1. Water services provided to the town of Kununurra include the supply and distribution of potable water, and the provision of wastewater collection and treatment services. Water services provided to ORIA Stage 1 include the provision of irrigation water and the collection of drainage waters.

Whilst ownership of the irrigation infrastructure assets in ORIA Stage 1 rests with the Water Corporation, operation of the system has been contracted to the Ord Irrigation Co-operative (OIC) (Section 2.2.8).

Water Corporation responsibilities in the region also include the management of Lake Argyle and Lake Kununurra (including the Diversion Dam).

The Water Corporation is an active participant, in conjunction with the Water and Rivers Commission and the OIC, in a programme for monitoring the quality of supply and drainage waters associated with ORIA Stage 1 and also a programme for monitoring groundwater levels.

2.2.8 Ord Irrigation Co-operative

The OIC was established in 1995 by local farmers to operate the irrigation system in ORIA Stage 1 on behalf of the asset owner, the Water Corporation. The OIC is owned by farmers in ORIA Stage 1 and is controlled by a seven-member Board. Prior to 1995, the irrigation system was operated by the Water Corporation, and it was the view of local farmers that the system could be operated in a more cost-effective manner by the OIC. The OIC contract includes the operation and maintenance of irrigation infrastructure assets and the provision of irrigation and drainage services in ORIA Stage 1.

The Water Corporation has retained ownership of the irrigation assets. As a consequence of retaining the ownership of assets, the Water Corporation holds an operating licence for the provision of water services in ORIA Stage 1 (Section 2.2.6). Future transfer of ownership of the ORIA Stage 1 assets is planned by the Water Corporation, at which time an operating licence would be required by the new owner.

The OIC, in conjunction with the Water and Rivers Commission, is currently involved in a monitoring programme of water quality and groundwater in ORIA Stage 1, and has ex-officio representation on the Ord Land and Water Management Plan Steering Committee discussed in Section 2.2.3.

2.2.9 AGWEST

AGWEST provides the full range of its services to growers in ORIA Stage 1. Research projects are undertaken by AGWEST at the Frank Wise Institute in the areas of horticulture, field crops, intensive beef production and new industries including cotton, sugar and processing tomatoes. Sustainability issues in ORIA Stage 1 are also addressed and other services are provided to address agricultural protection and quarantine issues.

AGWEST is an ex-officio member of the Steering Committee guiding the preparation of the Land and Water Management Plan, and operates an industry liaison group known as the Tropical Agriculture Team.

AGWEST has ten operational programmes that contain strategic directions. These include two industry-wide programmes—agriculture protection and sustainable rural development—and eight industry-development programmes.

The Sustainable Rural Development Programme applies the internationally agreed principles of ecologically sustainable development for agriculture. Its scope extends from on-farm production to off-farm considerations such as value-adding and community development opportunities associated with agriculture, and the social and environmental impacts of agricultural activities. The programme focuses on four key Statewide areas including regional strategic planning, catchment management, property management planning and rural community development. It is funded and managed in six regions, including the Kimberley (Agriculture Western Australia 1998).

The Agriculture Protection Program has two main objectives:

- to assist the agricultural industry to access premium markets for agricultural products that meet specifications for safety and quality;
- to help protect the State's agricultural industry from production and sustainability risks posed by animal and plant pests and diseases, and weeds.

AGWEST has also produced a series of 'Farmnotes' that sets out the responsibilities of landholders under agricultural Acts for:

- land use and general property management (Farmnote 8/91 Agdex 838)
- water and drainage (Farmnote 9/91 Agdex 838)
- livestock (Farmnote 10/91)
- cropping and horticulture (Farmnote 11/91 Agdex 838).

2.2.10 Commissioner for Soil and Land Conservation

The Commissioner for Soil and Land Conservation administers the *Soil and Land Conservation Act 1945*.

Under the legislation, notices of intention to clear land areas in excess of 1 ha must be lodged with the Commissioner for Soil and Land Conservation. When considering the notices of intention to clear, the Commissioner would normally seek comments from various Government agencies.

Land Conservation Districts can also be established under the *Soil and Land Conservation Act 1945*. Land Conservation District committees comprise groups of land users who

address local land degradation and management issues, and address long-term sustainable land use issues. The Commissioner is represented on all Land Conservation District committees, and the committees receive funding assistance through State Landcare WA.

There is an established Land Conservation District Committee for ORIA Stage 1 that consists of representatives from land users, the community, the Water Corporation, the Water and Rivers Commission, the Department of Conservation and Land Management (CALM), the OIC and AGWEST. The Committee meets monthly and, while its area of responsibility is ORIA Stage 1, it has in the past reviewed conservation issues in the broader region.

2.2.11 Ministry for Planning

The Ministry for Planning (MfP) was established in its current form in 1995 under the *Public Sector Management Act 1994*. Its major legislative responsibilities concern the administration of a number of statutes on behalf of the Western Australian Planning Commission. The Commission is responsible for granting subdivision, development, strata title, lease and licence approvals, and it also provides advice to the MfP on town planning schemes.

The MfP is preparing a Kununurra–Wyndham Area Development Strategy, which encompasses the north-eastern part of the Shire of Wyndham – East Kimberley, and includes ORIA Stage 1 and ORIA Stage 2. These documents are discussed further in Chapter 11.

In respect to ORIA Stage 1, the role of the MfP is to ensure that the Shire of Wyndham–East Kimberley Town Planning Scheme is effectively implemented. Recently, a new town planning scheme has been prepared by the Shire and this is currently being assessed by the MfP. Permission to advertise the scheme for public comment has been granted by the Western Australian Planning Commission and the MfP.

Any land rezoning in ORIA Stage 1 (and within the State in general) must be approved by the Western Australian Planning Commission. With specific reference to ORIA Stage 1, Commission approval would be required for any zoning of vacant Crown land or excissions from pastoral lease to facilitate expansion of irrigated agricultural activities.

2.2.12 Kimberley Development Commission

The Kimberley Development Commission (KDC) was established as a statutory authority under the *Regional Development Commissions Act 1993*. The purpose of the KDC is to promote an environment that is conducive to the balanced economic and social development of the Kimberley region. The KDC's statutory objectives are as follows:

- to maximise job creation and improve career opportunities in the region;
- to develop and broaden the economic base of the region;
- to identify infrastructure services to promote economic and social development within the region;
- to ensure that the general standard of Government services and access to those services in the region are comparable to that which applies in the Perth metropolitan area;
- to encourage, promote, facilitate and monitor the economic development in the region.

The KDC provides an integral component of a ‘whole-of-Government’ approach to the requirements of regional development. It assists in the coordination of responsibilities of a wide range of agencies having impact on regional development, and performs a role in identifying needs and ensuring a rationalised and appropriate application of Government resources to the region.

Whilst the KDC does not have an ongoing management role in ORIA Stage 1, it has participated in the facilitation of the preparation of the Land and Water Management Plan via enlistment of support from the Minister for Primary Industries.

2.2.13 Department of Conservation and Land Management

CALM was established under the *Conservation and Land Management Act 1984*. CALM is the State Government agency with responsibility for the conservation of Western Australia’s wildlife and with the management of lands and waters entrusted to it.

CALM manages more than 20 million ha of the State’s land and waters. The management role includes conservation functions, and management for recreation and tourism, to facilitate public enjoyment of the natural attributes of public lands and reserved waters in a manner that does not compromise conservation and other management objectives.

CALM involvement in ORIA Stage 1 has included:

- provision of advice on activities on land adjoining existing or proposed nature reserves or conservation zones;
- promotion of the reservation of the Packsaddle Swamp and Carr Boyd Ranges for conservation purposes;
- facilitation of the management of the impact of native animals on horticultural crops;
- research on the cultivation of tropical tree crops;
- provision of advice on the growing of tree crops, such as sandalwood;
- assistance with the assessment of actual and potential environmental weed species.

2.2.14 Department of Resources Development

The Department of Resources Development (DRD) is the State Government agency that facilitates the development of major industrial or resource-related projects in Western Australia. DRD functions include assisting project developers in the achievement of all necessary Government development approvals. It is also responsible for the negotiation of State Agreements between the Government and developers for subsequent ratification by Parliament.

DRD has recently been involved in the planning and facilitation of agricultural land development in and around ORIA Stage 1, and ORIA Stage 2 (including the Project Area).

2.2.15 Fisheries

Fisheries is responsible for the management of Western Australia’s fish resources and of the local pearling industry. Fisheries operates under Section 35 of the *Public Sector Management Act 1994* and administers four separate Acts:

- the *Fish Resources Management Act 1994*
- the *Fisheries Adjustment Schemes Act 1987*
- the *Pearling Act 1990*
- the *Fishing Industry Promotion Training and Management Levy Act 1994*.

Fisheries is also responsible for compliance with the *Commonwealth Fisheries Management Act 1991* in the Australian Fishing Zone.

Fisheries' key objectives are as follows:

- to uphold the harvesting and fishing of fisheries resources at ecologically sustainable levels;
- to maximise the economic, social and other benefits derived from Western Australia's aquatic biological resources;
- to increase the level of understanding of, and support for, strategies used by Fisheries to manage the State's fisheries resources;
- to minimise adverse human impacts on the aquatic environment;
- to assign access to aquatic biological resources in accordance with community priorities.

With respect to ORIA Stage 1, Fisheries has developed a commercial and recreational fishing management strategy for the Ord River. The goal of the strategy is to maintain the high quality recreational fishing and aquatic ecotourism industry currently found in the Ord River.

2.2.16 Environmental Protection Authority

The EPA is a statutory authority established under the *Environmental Protection Act 1986*. The key role of the EPA is to provide independent advice on environmental matters to the Western Australian Government.

Functions of the EPA include:

- the assessment of the environmental acceptability of development proposals and the provision of advice on these to the Minister for Environment;
- the formulation of environmental protection policies;
- the coordination of activities necessary to protect, restore or improve the environment of Western Australia.

With respect to ORIA Stage 1, the EPA is to review the Draft Interim Water Allocation Plan produced by the Water and Rivers Commission, and may assess any proposed extensions to ORIA Stage 1, and the proposed transfer of irrigation and drainage infrastructure in ORIA Stage 1 (Section 2.3.5).

2.2.17 Department of Environmental Protection

The Department of Environmental Protection (DEP) was established under the *Environmental Protection Act 1986*. Key functions of the DEP include:

- environmental systems management;
- the management of waste to meet health and environmental standards;
- the enforcement of pollution prevention and clean-up laws;
- environmental policy coordination;
- the provision of professional and technical support to the EPA, particularly in the area of environmental impact assessment of proposals and policy formulation.

The DEP's functions also include the study of environmental problems and the recommendation of solutions, the licensing of industries, and the delivery of environmental education and community awareness programmes.

In ORIA Stage 1, the DEP is responsible for environmental licensing of the existing raw-sugar mill. In the future, the DEP may be called upon to provide technical advice to the EPA in relation to EPA assessment work in and around ORIA Stage 1 (Section 2.2.16).

2.2.18 Shire of Wyndham – East Kimberley

The Shire of Wyndham – East Kimberley covers an area of approximately 121,000 km² and includes the townships of Wyndham and Kununurra, ORIA Stage 1, and the portion of ORIA Stage 2 within Western Australia. The Shire has offices in Wyndham and Kununurra, and council meetings are alternated between the two offices.

The Shire's responsibilities include, but are not limited to, the administration of planning requirements, development approvals, building licences, road maintenance and upgrading, and parks and reserves.

The Shire of Wyndham – East Kimberley Town Planning Scheme No. 4, currently under review, controls the planning and development of Kununurra and its surroundings, including ORIA Stage 1. As a consequence, buildings and land uses within ORIA Stage 1 require development consent from the Shire. Whilst it does not have a management role once land uses are approved in ORIA Stage 1, the Shire of Wyndham – East Kimberley ensures that ongoing compliance monitoring takes place. It is also represented on a number of management and consultation groups within the district.

2.2.19 Department of Land Administration

The Department of Land Administration (DOLA) was established to provide land administration products, services and information in Western Australia.

The primary role of DOLA is to provide the legal, geographic and administrative base for the orderly use of land by the Western Australian community. It does this by providing three key services: access to land information, a process for transacting land dealings, and administration of the Crown estate.

In recent years, DOLA has managed the conversion of vacant Crown land to leasehold or freehold title in relation to extensions of ORIA Stage 1 and the town of Kununurra. Future development of ORIA Stage 1 involving alterations to land tenure would require approval from DOLA, in addition to the compliance with all other relevant State and Federal legislation.

2.3 ENVIRONMENTAL ISSUES AND THEIR MANAGEMENT

ORIA Stage 1 has been operating for the purposes of irrigated agriculture since 1963, a period of over thirty years. Over that period, a wide range of commercial crops have been grown and farm management practices have changed in response to new crops, improved knowledge of local conditions and improvements in agricultural practices generally.

The following sections discuss environmental issues of relevance to ORIA Stage 1 and how they are currently being managed. A major initiative in this regard is the commencement of the development of a Land and Water Management Plan, a process incorporating significant community input. The Land and Water Management Plan is discussed separately in Section 2.3.5. Lessons learnt from ORIA Stage 1 and how these lessons have been applied to the Project are discussed in Section 2.4.

2.3.1 Pesticide and chemical use

A wide range of crops have been grown in ORIA Stage 1 from its establishment to the present day. Over the same period there have been a number of developments in the practices of irrigated agriculture relating to on-farm management. One of the major changes has been in the use of pesticides and chemicals. Current practices are profoundly different from those of the early development period of ORIA Stage 1, when the use of agricultural chemicals was extensive. The current use of chemicals has been tempered by lessons learnt from past practices, a shift in the mix of crops and the implementation of an integrated pest management strategy.

The integrated pest management strategy recently developed by AGWEST, in conjunction with local farmers, is an important facet of farm management. The strategy consists of a number of complementary activities designed to reduce the requirement for the application of chemicals to crops, including:

- the optimisation of chemical usage patterns and companion planting to complement and encourage the presence of beneficial insects;
- the eradication of disease host plants;
- the destruction of crops where appropriate;
- use of trap crops at the beginning and end of the season.

However, the integrated strategy does not eliminate the continued application of a variety of agricultural chemicals deemed necessary to maintain the agricultural and commercial viability of ORIA Stage 1.

In the early years, much of the chemical usage was associated with the cultivation of cotton. Cotton is currently grown in ORIA Stage 1 as large-scale trials in conjunction with the integrated pest management strategy, and the cotton grown has been genetically modified to increase its resistance to insect attack.

The range of chemicals currently utilised on farmland in ORIA Stage 1 is summarised in Table 2.3.

Table 2.3 Insect, Weed and Disease control chemicals in recent use on farmland in ORIA Stage 1

Crop	Insect Control*	Weed Control*	Disease Control*
FallowH		Atrazine Diquat Diuron Glyphosate Oxyflurofen Parquat	
Soya bean	Chlorpyrifos Diazinon Endosulfan Methomyl Monocrotophos Synthetic pyrethroids Trichlorphon	Bentazone Diphenylether compound Diquat Trifluralin	
Sugarcane		Asulam Atrazine Bromoxynil Diquat Diuron Loxynil M.S.M.A Paraquat	Prochloraz
Maize	Chlorpyrifos Primicarb Synthetic pyrethroids Trichlorfon	Atrazine Diquat Glyphosate Oxyflurofen Paraquat	
Hybrid seeds - Maize and Sorghum	Chlorpyrifos Endosulfan Methomyl Primicarb Synthetic pyrethroids	Atrazine Diquat Oxyflurofen Paraquat	
Cucurbits	Carbaryl Chlorpyrifos Dimethoate Endosulfan Metasystox Methomyl Parathion Primicarb Sethoxydim Synthetic pyrethroids Trichlofon	Fluazifop Sethoxydim	Copper compounds Mancozeb Oxadixyl Propineb Pyrazophos Triadimenol Tridemorph
Chick Pea	Chlorpyrifos Endosulfan Methomyl Monocrotophos Parathion Synthetic pyrethroids	Diquat Flauzifop Paraquat Sethoxydim Trifluralin	

Table 2.3 Insect, Weed and Disease control chemicals in recent use on farmland in ORIA Stage 1 (cont)

Crop	Insect Control*	Weed Control*	Disease Control*
Sunflower Hybrid Seed	Carbaryl Chlorpyrifos Endosulfan Methomyl Synthetic pyrethroids	Diquat Fluazifop Glyphosate Oxyflorfen Paraquat Sethoxydim Trifluralin	
Cotton ^o	Amitrez Bifenthrin Chlorpyrifos Diafenthiuron Methomyl Monocrotophos Piperonyl Butoxide Pirimicarb Sponsad Synthetic pyrethroids Thiocarb	Pyrithiobac-sodium	

* Many chemicals have similar properties, hence only a small range of those shown are generally used on any particular crop. Selection depends upon pest species present and farmer preference.

H Generally applies to most crops prior to planting in conjunction with mechanical cultivation.

^o Grown as part of large scale crop trials

Sources: Cook 1997 and R Leonard, Ord District Co-Operative Limited pers. comm. December 1999.

In addition to chemical usage on farmland, chemicals such as acrolein are used for control of aquatic weeds in the irrigation infrastructure (Section 2.3.4).

The pesticide currently of most concern in ORIA Stage 1 is endosulfan, a chemical known to be highly toxic to some fish and other aquatic species. Endosulfan is used extensively throughout ORIA Stage 1 on approximately 7,000 ha of the cropped area. The pesticide is used to control caterpillar pests in melon crops, soy beans, sweet corn, chick pea, culinary beans and hybrid seed crops. Endosulfan is used within a spray calendar in order to prevent over-use and any resultant build-up in resistance among target pests. It has very little effect on the beneficial insects that are part of the integrated pest management strategy.

Endosulfan usage was implicated in fish kills reported between 28 June 1997 and 25 August 1997 in the Dunham River, mainly between the Dunham River bridge and the confluence of the Dunham River and the Ord River. These incidents involved a gross estimate of some 200 to 300 fish killed, including bony bream, catfish, barramundi, archer fish and pop-eyed mullet.

A joint investigation into the fish kills was undertaken by the Water and Rivers Commission, and Fisheries. The investigation comprised an extensive 'snapshot' of water quality in the Ord River and environs and included data collected by the OIC. The Water and Rivers Commission (1998) investigation concluded that the Dunham River fish kills appeared to have been caused by endosulfan toxicity, which might have been exacerbated by stagnant water conditions in the Dunham River.

It is believed that mobilisation of endosulfan from farms is due mostly to molecular adsorption by very fine colloids such as clay particles, and that lesser amounts of mobilisation may be via solutions as endosulfan sulphate (Doupé et al. 1998). AGWEST

has been working with local farmers to refine a management strategy, aimed at reducing endosulfan loads in water exported from farms. The AGWEST integrated pest management strategy comprises the following recommendations:

- a voluntary ban on the use of endosulfan during the wet season;
- adoption of endosulfan spraying practices that:
 - comply with the National Registration Authority for Agricultural and Veterinary Chemicals (NRA) review recommendations on endosulfan usage (described below);
 - prevent the application of the chemical to areas having free-standing water in either the furrows or tail drains;
- examination of alternative pesticides to endosulfan that have similar low toxicity to beneficial insects.

The Ord Cucurbit Growers Group introduced a draft Code of Practice for Endosulfan Use in 1998. Based on experience in that year a revised Code of Practice using scouting for insect populations on crops, insect pest thresholds and spray strategies has been implemented for 1999.

The NRA recently completed a review of endosulfan resulting in a range of new restrictions on its use. Most of these restrictions will appear as new instructions on the registered label of endosulfan products by 30 June 1999, and will have the following effects:

- Endosulfan will become a restricted product and only persons with Farmcare training or similar accreditation will be able to purchase and use endosulfan products.
- Records of all endosulfan applications will need to be kept in accordance with Farmcare guidelines acceptable to the NRA.
- Except for orchards and cotton, all other crops will be restricted to two applications of endosulfan per year, unless irrigation tailwater and storm runoff water can be captured on farm (up to a 25 mm of isolated rainfall event).
- When endosulfan is used on cotton, current industry best management practices will have to be followed, in addition to the following restrictions:
 - There will be an absolute limit of three sprays or equivalent (not exceeding a total of 2,250 g of active ingredient per hectare) per crop per season of endosulfan.
 - Aerial application of endosulfan will only be permitted during specified time windows—1 December to 15 January for ultra-low-volume (ULV) application, and 15 November to 15 January for emulsifiable concentrate application (note that cotton is not grown in the ORIA during these periods).
 - Aerial application will be restricted to crops over 30 cm in height for ULV application and 20 cm in height for emulsifiable concentrate.
 - Mandatory downwind buffer zones will be required unless the appropriate neighbour gives written permission to waive the buffer. The buffer will depend on the formulation or application method as follows: 1,500 m for ULV application, 750 m for application of emulsifiable concentrate by air and 200 m by ground respectively.

- The use of high-volume, large-droplet-placement technology will be required for all emulsifiable concentrate applications, whether by air or ground, according to NRA specifications, yet to be published.
- Mandatory prior notification of neighbours surrounding the sprayed areas will be required for application within 1,500 m for ULV application, 750 m for emulsifiable concentrate application by air and 200 m for emulsifiable concentrate application on the ground.
- Workers will not be permitted to enter a crop within two days of treatment with endosulfan, unless they are wearing the personal protective equipment specified on the label. In the case of hand-weeders, no entry into the treated area will be permitted for two days following treatment and some personal protective equipment will be required after that period.
- Wherever possible, farmers should use spray equipment with enclosed cabins.
- Manual flagging for aerial application will not be acceptable unless an enclosed cabin or other engineering controls protect the flagger.
- Withholding periods will not be less than two days. Users should ensure that they identify the appropriate withholding period before they use the product.

The NRA has also determined that many of the existing uses of endosulfan will not continue beyond 1999–2000, unless producer industries and the chemical manufacturers can satisfy the NRA that endosulfan can continue to be used without unnecessary risk to the environment, consumer and worker safety.

The NRA has also specifically requested:

- worker exposure data for the handling and application of endosulfan in a range of agricultural industries;
- evidence of reduced environmental contamination with endosulfan;
- residue data to support maximum residue limits for most of the existing uses;
- implementation of spray drift minimisation strategies for all crops.

At the time of development of ORIA Stage 1 in the early 1960s, irrigation systems were commonly designed as ‘flow through’ or flushing systems. However, such designs do not constrain the pesticides within the farm boundaries. In more recent times, irrigation systems in Australia have been designed around the need to capture irrigation tailwater and return it for use on farms. This practice was initially developed as a means of augmenting irrigation water supplies but has since been shown also to be beneficial in reducing off-farm impacts from pesticides in general.

Large areas of sugarcane have been grown in ORIA Stage 1 in recent years. This crop has a low requirement for chemicals compared with other crops, which has reduced the risks associated with off-farm impacts. In addition, sugarcane is a perennial crop, providing cover during the wet season and thereby reducing sediment loss from farms.

Strategies for the management of pesticides and chemicals in ORIA Stage 1 are being developed and implemented. Endosulfan usage in the future will be more tightly controlled and imminent changes to State legislation will require training for farm staff involved in the

spraying of chemicals, and accreditation of commercial spray operators under a national standards system.

2.3.2 Groundwater issues

Extensive historical data exist on the behaviour of groundwater in ORIA Stage 1. Groundwater monitoring bores were installed by the Public Works Department in 1964, and in subsequent years those bores have been augmented by additional bores installed by the Water and Rivers Commission and AGWEST. The current database of groundwater information includes time period analysis of groundwater levels and salinity in a number of locations in ORIA Stage 1.

Data gathered from the network of monitoring bores indicate that groundwater levels in ORIA Stage 1 have risen over a significant proportion of the area. However, it is noted that after more than thirty years of irrigation, in only two localised areas is groundwater now less than 2 m from the surface. Groundwater levels have not affected land use in ORIA Stage 1 to date and groundwater remedial measures have therefore not been required.

The monitoring data also show that no areas in ORIA Stage 1 have been affected by salinity, and groundwater salinity levels are generally within the range tolerated by most crop species. However, in certain areas, groundwater salinity levels may be sufficient to reduce yields if groundwater were to rise to the surface.

A water and nutrient balance of the Ivanhoe Plain was commissioned by the Water Corporation in 1997 in order to investigate and quantify the sources of accession of groundwater. Results of the analysis are as follows:

- There is significant contribution to groundwater recharge from Lake Kununurra in the southern portion of the Ivanhoe Plain, but the recharge is well drained to the Ord River through highly transmissive river gravels.
- The M1 Channel has a significant influence on the groundwater levels in its vicinity, but the contribution to groundwater recharge by the channel has decreased slightly in absolute terms in recent years.
- The volume of recharge from irrigated farmland has increased since 1970, and especially since 1990.
- Groundwater accession from 1966 to 1990 averaged approximately 5% of the applied irrigation water volume, and since 1990 has been approximately 10%.
- The proportion and volume of recharge from the M1 Channel versus recharge from the irrigated farmland has changed considerably over time, ranging from an estimated 69% contribution from the M1 Channel and 31% accession from farmland in 1970; through to an estimated 19% recharge from the M1 Channel and 81% accession from farmland in 1996.

Groundwater levels in ORIA Stage 1 may require management at some point in the future. Numerous management options are available, including extraction of groundwater from permeable gravel beds via dewatering bores, installation of subsurface drains, tree plantings and improved farm drainage systems.

Management of groundwater issues in ORIA Stage 1 is receiving considerable attention as part of the development of the Land and Water Management Plan (Section 2.3.5).

2.3.3 Surface water issues

Drainage waters from ORIA Stage 1 are discharged into the Lower Ord River at a number of locations, predominantly between the mouth of the Dunham River and Drover's Rest. In addition, drainage waters from the Packsaddle Plain are discharged into the Dunham River, a tributary of the Ord River, via Packsaddle Creek. Drainage waters comprise farm irrigation water and rainfall runoff.

Water quality monitoring has been implemented in ORIA Stage 1 since the late 1970s. Over that period, the mix of crop types grown in ORIA Stage 1 has changed considerably and much of the early data have limited relevance to current practices. However, in more recent times, various water monitoring programmes have been undertaken in and around ORIA Stage 1.

In January 1996 a monitoring programme was instigated by the OIC, the Water Corporation and the Water and Rivers Commission. The water quality parameters monitored at approximately thirty sites include salinity, electrical conductivity, turbidity, alkalinity, pH, hardness, and the presence or concentration of iron, manganese, sodium, nitrous oxide, ammonia, and various trace elements. Sampling for pesticide residues including dieldrin, DDE (the breakdown product of DDT) metabolites, organochlorines and organophosphates has also been undertaken at irregular intervals.

Schoolchildren have also analysed water quality in ORIA Stage 1 during the period May to September since 1997 as part of the 'Ribbons of Blue' programme, the Western Australian component of the national Waterwatch Australia programme.

Additional water quality data also exist from an investigation by Doupé et al. (1998) and from ongoing monitoring by the Water Corporation and Ord Sugar Pty Ltd in the M1 Channel, upstream and downstream of the discharge points for the Kununurra Wastewater Treatment Plant and the sugar mill respectively.

The results of the water quality monitoring have shown that the sugar mill and, to a lesser extent, the Kununurra Wastewater Treatment Plant have been sources of the nutrients phosphorus and nitrogen for water in the M1 Channel. While not large in absolute terms, these sources were significant in comparison with the low levels of nutrients generally found in the water in Lake Kununurra. The sugar mill discharge has recently been modified to avoid the discharge of silt and nutrients into the M1 Channel.

Drains discharging into the Ord and Dunham rivers from ORIA Stage 1 contain varying quantities of nutrients. As expected, measured nutrient levels downstream of the drain discharges are slightly above the low natural level of nutrients in the Ord River due to the significant dilution provided from river flows.

A number of chemicals detected in the monthly water quality samples collected by the Water and Rivers Commission and the OIC are no longer in use in ORIA Stage 1; these include dieldrin, chlordane, heptachlor and DDT. The long half-lives of these compounds mean that they will continue to be detected for many years. Chlordane has been found at levels of 0.01–0.06 µg/L, DDE at levels of 0.02–0.39 µg/L and heptachlor in the range of 0–0.2 µg/L. While some of these levels are currently above guidelines applicable to the receiving waters, the chemicals are no longer in use and their concentration in the receiving waters should continue to reduce with time.

Endosulfan levels recorded in irrigation drains are in the range of 0–1.1 µg/L, with the majority of levels ranging from undetectable to 0.2 µg/L. Endosulfan recordings in the Ord River, with the exception of one reading, have all been below 0.1 µg/L. Higher readings have been recorded during the dry season in the Dunham River, when flows in this river are predominantly composed of irrigation tailwater.

2.3.4 Terrestrial and aquatic weeds

Terrestrial weeds occurring in and around ORIA Stage 1 are predominantly introduced plant species that are able to out-compete native species. These species include *Parkinsonia aculeata*, *Leucaena leucocephala*, *Calotropis procera* and *Xanthium strumarium* (Noogoora burr).

Responsibility for weed management varies with species and location. CALM has responsibility for the management of weeds growing in or near conservation reserves under its management. In other instances control of weeds is the responsibility of the landowner, especially for species declared noxious weeds by the Agriculture Protection Board under the *Agriculture and Related Resources Protection Act 1976*.

A large area of land on both banks of the Lower Ord River is in quarantine for the control of Noogoora burr. Quarantine restrictions in the Mantinea area were lifted by AGWEST in 1997. AGWEST is also currently investigating the introduction of a natural predator (a bruchid beetle) of *Leucaena leucocephala*, to control its spread outside areas where it is grown for cattle feed.

The Ord River is currently free of any introduced aquatic weeds. However, the control in water levels brought about by the irrigation scheme infrastructure has led to proliferation of a *Typha* (Cumbungi) in Lake Kununurra and along the banks of the lower Ord River. This growth reduces access to the water edge, interferes with navigation and restricts the ability of farmers to pump directly from Lake Kununurra.

Irrigation channels provide ideal growing conditions for other native aquatic species such as *Vallisneria* sp. (ribbon weed) and *Potamogeton* sp. (curly pond weed). The Water Corporation has used a combination of mechanical clearing and herbicides to control the weed growth in the irrigation channels. Herbicides, containing acrolein as the active ingredient, are introduced at strategic locations along the channels approximately eight times a year.

2.3.5 Environmental management framework

ORIA Stage 1 was developed before environmental legislation existed in Western Australia. As a consequence, no environmental assessment or management plan has ever been developed for ORIA Stage 1. Environmental management in ORIA Stage 1 currently relies upon the compliance of all individuals, groups and agencies with laws and statutes that apply to prevent pollution and degradation of land. This approach is common for agricultural schemes throughout Australia.

Absence of a clear management framework can have limitations:

- The responsibility for environmental management is not always clear for trans-boundary issues such as ground- and surface water management.

- Difficulties can arise if responsibilities for environmental management belong to individuals or groups who do not have adequate technical or financial resources.
- Minimum standards may be achieved rather than best-practice performance in environmental management.

The need for a co-ordinated approach to the management of environmental issues has been recognised by the various stakeholders in ORIA Stage 1. Two important initiatives are being undertaken to address this issue; the preparation of a Land and Water Management Plan and an assessment of the environmental implications of the proposed handover of irrigation scheme assets.

The Land and Water Management Plan

The local farming community has taken the initiative in commencing preparation of a Land and Water Management Plan to address the environmental issues, and ensure long-term sustainability of ORIA Stage 1.

Preparation of the Land and Water Management Plan commenced in 1996, and since March 1998 has been directed by a Steering Committee (Section 2.2.3). Financial contributions, or contributions in kind, for the purposes of employing coordinators and completing various studies and monitoring programmes have been supplied by a range of organisations including the Tropical Agriculture Team, AGWEST, the National Landcare Program, the Water and Rivers Commission, the Water Corporation, the OIC and local farmers.

The Land and Water Management Plan is to address the potential impact, both environmental and economic, of all uses of land and water resources of ORIA Stage 1. The output from the Land and Water Management Plan is to be a framework for the implementation of appropriate environmental management practices and will result in an increased awareness and understanding of environmental issues by farmers and the wider community.

From the inception of the Land and Water Management Plan, there has been extensive community consultation on environmental issues relevant to ORIA Stage 1. Community consultation has been supported through the production of a bimonthly newsletter distributed to approximately 300 people.

In March 1998, an Environmental Symposium was convened in Kununurra, attended by about 100 people. At the symposium, papers were presented by representatives from AGWEST, the Water and Rivers Commission, the Conservation Council of Western Australia, Fisheries, local farmers and industry, and other interested parties. The purpose of the symposium was to raise awareness of local environmental issues. The Land and Water Management Plan Steering Committee was elected by those people who were present at the symposium.

Discussion meetings with interested community groups started after the symposium. Over the past year contact was made with a large number of groups with interests in land and water management issues. The community consultation was synthesised into an Issues Paper published in November 1998. Groups who had input into the Issues Paper included:

- the East Kimberley Recreational Fisheries Advisory Council
- the Lower Ord Management Group

- the Tropical Agriculture Team
- the Kununurra Horticulture Producers Association
- the Ord Cucurbit Growers Group
- the ORIA Land Conservation District Committee
- the Care of the Ord Valley Environment Group
- the Ord Mango Growers Association
- the Kununurra Ratepayers Association
- the Ord Development Council
- the Shire of Wyndham – East Kimberley
- the Ord River District Co-operative
- the OIC.

In March 1999, a community meeting was convened in Kununurra to finalise the key issues that would be addressed by the Land and Water Management Plan and to develop implementation strategies. Recommendations adopted at the meeting were as follows:

- The best way to develop strategies would be to coordinate working groups, known as ‘Local Action Groups’, which would focus on particular issues.
- Issues would be consolidated in four areas—‘river’, ‘land’, ‘town’ and ‘conservation’—and a Local Action Group would be assigned to each.
- Local Action Groups would include representatives from different sectors of the community as well as a representative of the Land and Water Management Plan Steering Committee, the latter to help with communication between groups as well as with coordination and organisation.
- A Technical Advisory Group, comprising representatives from agencies and local industry should be formed and its expertise made available to the Local Action Groups.

The meeting confirmed that a high level of community involvement was desired during the development of the Land and Water Management Plan so that the final plan would benefit from a corresponding high level of community ownership. Completion of the final plan is scheduled for March 2000, after which there will be a period of negotiation with stakeholders to confirm roles and responsibilities for implementation of the Plan.

Future Responsibility for Irrigation Scheme Assets

The Water Corporation intends to hand over the bulk of the existing irrigation scheme assets to the OIC (Sections 2.2.7 and 2.2.8 refer). It is envisaged that after the transfer, the Water Corporation would retain ownership of and operating responsibilities for the Ord River Dam, the Diversion Dam, the bulkwater metering assets for each of the Ivanhoe and Packsaddle irrigation areas, and the M1 Channel. In doing so, the Water Corporation would become a supplier of bulk water, rather than the owner/operator of the whole scheme.

The proposed transfer of assets and responsibilities from the Water Corporation to the OIC has raised the issue of ongoing responsibility for environmental issues and their management. The Water Corporation and the OIC have agreed to define their individual

environmental responsibilities, and those that would remain as joint responsibilities, and have them assessed by the EPA.

Under recent amendments to Administrative procedures for Environmental Impact Assessment under the *Environmental Protection Act 1986*, there is now provision to assess and set environmental conditions on a proposal of this nature with a new form of environmental document known as an Environmental Protection Statement. An Environmental Protection Statement may be prepared in the near future in relation to the proposed transfer of irrigation scheme assets should the EPA agree to this approach.

2.4 IMPLICATIONS FOR THE PROPOSED DEVELOPMENT OF THE PROJECT AREA

The development of ORIA Stage 1 pre-dated the establishment of institutionalised and formal environmental impact assessment procedures that currently exist under the *Environmental Protection Act 1986*.

As stated previously, since the early years of development of ORIA Stage 1 there has been significant change, both in Australia and overseas, with respect to irrigated agriculture techniques and community awareness of environmental issues. Over the same period, there has also been a significant change in the mix of crops grown in ORIA Stage 1, and in the resultant environmental implications of commercial cultivation of those crops.

The impacts of ORIA Stage 1 on the environment, and the management of environmental issues, are now priority concerns for local farmers and a range of stakeholder groups. This is clearly evidenced by the initiatives to prepare a Land and Water Management Plan and to have the EPA review new management arrangements and responsibilities.

Currently, various groups and individuals hold a range of opinions on the status of the environment in and surrounding ORIA Stage 1. Whilst many argue that environmental issues are being managed in a pragmatic fashion in ORIA Stage 1, others take the view that existing environmental issues should be resolved completely prior to any consideration of expansion of ORIA Stage 1 and/or development of ORIA Stage 2 (including the Project Area).

It is the view of Wesfarmers–Marubeni and the Water Corporation that development of the Project Area could be managed in an environmentally sustainable manner. However, it is only natural that any expansion should take into account environmental issues identified in ORIA Stage 1. The following sections summarise the approach proposed in relation to the Project, with particular reference to some of the environmental issues that have arisen in ORIA Stage 1.

2.4.1 Pesticide and chemical use

The greater part of the Project Area would be devoted to the growing of sugarcane, a crop that has a low requirement for pesticides, and no requirement for the use of endosulfan.

Experience from ORIA Stage 1, and from other irrigation areas around Australia, has shown that on-farm management of irrigation and stormwater is required in order to manage the off-farm impacts of sediment, pesticides and other agricultural chemicals. For this reason, current best-practice on-farm water management measures would be adopted for the Project.

All farm units within the Project Area would be developed with tailwater return systems capable of collecting and returning on-farm all irrigation water runoff. The tailwater return systems would be designed in such a way as to also perform the function of first-flush stormwater collection systems, with the collected stormwater also being returned on-farm for use as irrigation water. The design capacity of the first-flush stormwater collection systems would be 12 mm of stormwater runoff for farm units devoted to sugarcane and 25 mm for farm units which may be used to grow crops that require the use of endosulfan or similar pesticides.

Recent advances achieved in pesticide use and management in ORIA Stage 1 would be adopted, and wherever possible enhanced, in the Project Area. As a minimum this would include:

- provision of buffers between farms and water courses;
- the adoption of the integrated pest management strategy developed in ORIA Stage 1 where appropriate;
- the adoption of the spray calendar developed each year for ORIA Stage 1;
- the adoption of AGWEST recommendations (Section 2.3.1) for on-farm management of endosulfan;
- compulsory training for all farm staff who would be required to handle and spray chemicals;
- compulsory accreditation of all commercial spray operators to a national standards system.

In addition, the above management measures would be supported by a comprehensive monitoring programme for pesticides and chemicals in the receiving environment. The monitoring programme would be undertaken as part of the environmental management framework for the Project Area (Section 2.4.5 and Chapter 15), and the results would be used to modify on-farm practices wherever necessary.

2.4.2 Groundwater issues

Experience gained in ORIA Stage 1 with respect to the rise of groundwater levels underlying irrigated black soil plains has been applied to numerical groundwater modelling of the Project Area (Chapter 6 refers). In addition, results gained from test pumping from gravel aquifers underlying the black soils in ORIA Stage 1 have confirmed that approach as a means of satisfactorily controlling groundwater levels. Pumping from bores now forms the basis of the groundwater control plan being developed for ORIA Stage 1.

A proactive groundwater management strategy is proposed as part of the Project. This strategy seeks to manage groundwater levels from project inception to ensure the sustainability of irrigated agriculture on the Project Area. Key elements of the strategy are as follows:

- engineering design standards would comply with current best practice for all irrigation channels and regulating storages intended to convey or store water for prolonged periods. These design standards would specify the minimum thickness and compaction levels of the clay lining systems provided to minimise accessions to groundwater;

- regulating storages would be sited to areas that naturally contain greater surface thickness of the less permeable Aquitaine clays;
- drains for stormwater runoff would be designed with broad channel inverts to minimise excavation, thereby containing the channel inverts where possible in the naturally occurring less permeable surface soils;
- comprehensive supervision and quality assurance procedures would be adopted to ensure that the design intent is fulfilled during construction;
- crop watering strategies that maximise the water uptake by crops and minimise the water loss to groundwater would be utilised;
- groundwater levels would be controlled via the utilisation of bores and subsoil drains;
- a comprehensive monitoring programme for groundwater levels and quality, and use of the collected data to modify management practices would be practiced.

An important lesson learned from the experiences with ORIA Stage 1 is that clear responsibility for groundwater management is required together with responsibility for funding of groundwater control measures. Unlike ORIA Stage 1, where it has been difficult to allocate such responsibilities, the Project would involve the clear allocation of responsibilities for groundwater management at inception through the proposed environmental management framework (Chapter 16 refers). The benefit of this approach is that it allows the cost of sustainable groundwater management to be included in project feasibility calculations. In addition, it would allow all current and future participants in the Project to be aware of their long-term financial commitment with respect to groundwater management, and permit them to plan accordingly.

2.4.3 Surface water issues

The Project would be designed, constructed and operated in accordance with current best-practice requirements with respect to surface water management. In particular, this would involve the following features:

- Irrigation water would be provided on a full economic cost recovery basis, which would provide a strong economic incentive for efficient water usage on farms.
- All farm units would be provided with tailwater return systems that would also act as first-flush stormwater collection systems, aimed at protecting the quality of receiving waters as well as promoting efficient water use.
- The irrigation water distribution infrastructure would be operated from a centralised control centre to provide a high level of water distribution efficiency.
- Regulating storages would be provided along the route of the main supply channels in order to provide additional capacity for times of peak water use. At other times they would provide buffer capacity that would even out flows in the channels, thereby minimising the need to discharge water to the drainage system.

By comparison with ORIA Stage 1, the above features should result in higher efficiency of water use as well as a greater level of containment of silt and agricultural chemicals on the farms. The most obvious difference would be the virtual elimination of dry season flows from the Project Area.

2.4.4 Terrestrial and aquatic weeds

Existing statutory requirements in Western Australia for the control of weeds in and around ORIA Stage 1 would also apply to the Project Area. These requirements would be augmented or modified as appropriate by the statutory requirements applicable within the Northern Territory.

The Project allows for the monitoring and management of terrestrial and aquatic weeds in a defined buffer zone within the Project Area. This responsibility would be fulfilled as part of the environmental management framework to be established as part of the Project (Section 2.4.5 and Chapter 15).

2.4.5 Environmental management framework

Section 2.2 provides a brief description of the individuals, grower groups, businesses and Government agencies that are identified in this ERMP/draft EIS as currently having an interest in ORIA Stage 1 and possibly sharing responsibility for environmental management in some way. Difficulties associated with such a diverse distribution of responsibilities, sometimes to groups without adequate technical or financial resources, have been recognised by farmers within ORIA Stage 1. This recognition has led to the inception of the development of a Land and Water Management Plan, which is to guide environmental management of ORIA Stage 1.

The Project has an advantage over ORIA Stage 1 in that current knowledge and expectations with regard to environmental management can be incorporated into development plans from the outset. For example, as mentioned in previous sections, all farm units would be equipped with current best practice on-farm water management measures comprising first-flush stormwater collection and irrigation tailwater return systems.

In addition, the early years of project development and operation would largely be undertaken by one corporate farmer, which would make it easier to develop environmental management systems and easier to account for responsibility for their implementation than would be the case if a large number of smaller farmers were involved. An environmental management framework, described in detail in Chapter 16, would be established at Project inception to ensure that environmental management responsibilities are clearly identified and appropriately implemented and funded as part of the Project.

An important objective taken into consideration during the development of the proposed environmental management framework was the need for it to deal efficiently and fairly with respect to future ownership, particularly to cater for a potential selldown in part or whole of the corporate farm. The proposed framework fulfills this objective by clearly identifying the roles and responsibilities of all parties and by providing a mechanism for the transfer of these responsibilities via contractual arrangements.

The proposed environmental management framework has been developed in accordance with the concept of self-regulation in order to promote greater ownership by all parties of the responsibilities for environmental management. However, a high level of public and regulatory authority review would be provided, involving:

- review of this ERMP/draft EIS and completion of the environmental impact assessment procedure, including the setting of environmental conditions;

- the potential for focussed and ongoing community consultation within the proposed environmental management framework;
- public scoping of the Environmental Management Plan for the Project, including subsequent revisions and updates;
- publication of annual reports containing results of ongoing monitoring programmes, developed as part of the environmental management plan, and compliance with environmental conditions.

It is noted that the Land and Water Management Plan proposed for ORIA Stage 1 is also being developed with extensive community involvement in order to increase ownership and awareness of environmental management by farmers and the wider community.

3 Description of the Project

This chapter describes the Project, which would ultimately produce 400,000 t/a of raw sugar and 160,000 t/a of molasses for sale on export markets. The development and operation of the projected new agricultural lands are described, as well as the associated infrastructure facilities. Other topics covered include processing of the sugarcane crop into the final products, management of the waste products produced by the raw-sugar mill, and construction issues.

3.1 PROJECT SCOPE AND TIMING

3.1.1 Scope

The Project is based on development of flood-irrigated farmland within the Project Area predominantly for sugarcane production to provide feedstock for the operation of a 400,000 t/a raw sugar mill. The raw sugar and the molasses by-product would be trucked from the mill to purpose-built storage facilities at Wyndham where they would await export.

Wesfarmers–Marubeni would own and operate the proposed raw-sugar mill and associated export facilities at the port of Wyndham. Wesfarmers–Marubeni would also own approximately 29,000 ha of irrigated farmland and operate that farmland as one sugarcane plantation business. Over time and as the supply of cane with the desired quality attributes becomes well proved, the corporate farm may be gradually subdivided and sold down to independent sugarcane growers.

Approximately 3,000 ha of land within the Project Area would also be made available by Wesfarmers–Marubeni for sale to independent farmers on an unconditional basis with respect to the types of crops grown. The crops grown on this land may or may not include sugarcane.

The off-farm irrigation, drainage and flood protection infrastructure would be developed, owned and operated by the Water Corporation. It is envisaged that the cost associated with the development and operation of the irrigation infrastructure would be recovered through the sale of irrigation water to the corporate and independent farms.

Table 3.1 provides a summary of the scope of the Project.

Table 3.1 Scope of the Project

Item	Amount
Land within the Project Area	76,000 ha*
Land managed for conservation**	41,000 ha*
Infrastructure area	3,000 ha*
Wesfarmers–Marubeni sugarcane estate	29,000 ha*
Land for independent farms	3,000 ha*
Land outside Project Area	
M2 Channel (Lake Kununurra to Project Area)	690 ha
Wyndham Port facilities	1 ha
Production	
Raw-sugar	400,000 t/a
Molasses	160,000 t/a
Infrastructure	
Irrigation channels	160 km
Annual water requirement	740 GL
Drains	153 km
Flood protection levees	142 km
Balancing storage dams (operating volume)	5.6 GL
Roads	161 km
Power lines	165 km
Wyndham port	
Raw-sugar store	180,000 t
Molasses store	75,000 t

* Areas rounded to the nearest '000 ha.

** Includes some 2,000 ha that would otherwise be suitable for farming.

3.1.2 Relationship to other developments

The Project would essentially be independent of other irrigation developments in the region.

The Project would abut the easternmost extremity of ORIA Stage 1 on the Ivanhoe Plain in the vicinity of Cave Spring Gap. ORIA Stage 1 is served by the M1 Channel, and the proposed M2 Channel would be developed in a parallel alignment to the M1 Channel for the first 23 km of its length from the off-take at Lake Kununurra. It is envisaged that the M2 Channel would have a stand-alone management and operation system.

It is possible that some farmers in ORIA Stage 1 may wish to expand their current operations into the Project Area. Even under these circumstances any farm operations in the Project Area would need to be consistent with the environmental commitments made in this ERMP/draft EIS and the environmental conditions imposed on the proposed development.

Government is also considering the development by others of other components of ORIA Stage 2, described in Section 1.1.3, for agricultural purposes. This land is located as follows:

- Mantinea Plain;

- west bank of the Ord River;
- Carlton Plain.

All of the above developments, if they proceed, would share the same source of water derived from releases from Lake Argyle; however, they would be independent of the Project, and would require separate environmental assessment prior to proceeding.

3.1.3 Programme

The development schedule (Figure 3.1) would be staged to maximise the delivery of cane to the sugar mill in the early years, so as to underpin the economics of the Project. It is envisaged that farm development would be substantially complete in 2003 and the first cane would be harvested for processing by the mill in the same year, coinciding with the completion of mill construction. It is envisaged that full cane production would be achieved in the dry season of 2005.

Construction of the sugar mill would continue during both the dry and wet seasons. Other construction would occur predominately during the dry season as ground conditions during the wet season would prohibit significant land development activities. Cane-planting requires ‘seed cane’ harvested from the previous season’s growth. On an indicative basis, one hectare of cane would produce sufficient seed cane to plant a further 10 ha. The development schedule allows for the progressive development of seed cane stocks from an initial nursery of 1,000 ha, which would probably be developed on the Weaber Plain in 2001.

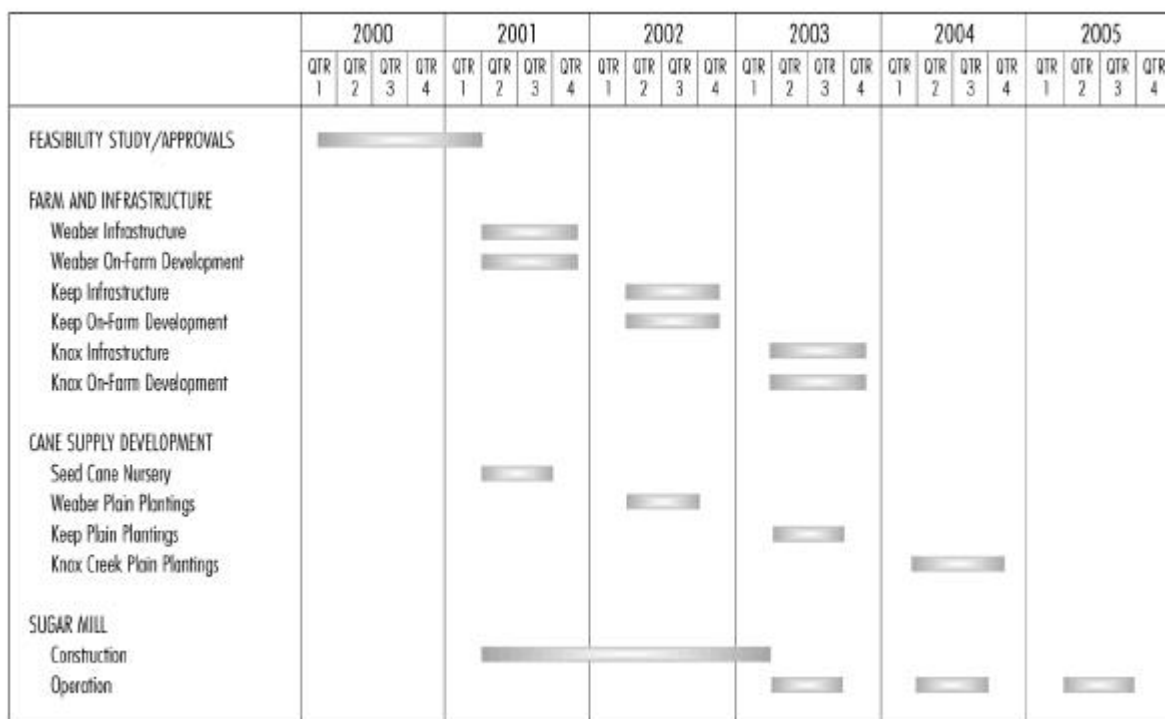


Figure 3.1 Indicative Development Schedule

3.2 FARM DEVELOPMENT AND OPERATION

3.2.1 Farm development

The agricultural component of the Project is based upon the development of a series of farm units of, notionally, 400 ha each for both the Wesfarmers–Maurbeni corporate farm and farms that would be owned by independent farmers. The farm units would be linked by the infrastructure described in Sections 3.5 and 3.6 and predominantly provide sugarcane for a raw-sugar mill described in Section 3.7.

The farm development (on-farm irrigation and potable water supply, power and telecommunications, and access roads) has been designed so as to readily enable subdivision and sale of the farmland at some point in the future.

The farm unit layout is governed to a large extent by the desire to achieve uniform water application to the crop. This necessitates that farm units (or blocks within a unit) have:

- uniform soils
- uniform slopes
- uniform row/furrow lengths.

Farms would be designed to facilitate the operation of large-scale farm equipment to optimise economies of scale. The width of farm blocks, or bay length, would be approximately 500–800 m, whilst the length of blocks would be maximised subject to the geometry of the three plains. The limiting factor with respect to row length would be the potential for accumulation of trash in the furrows. The naturally flatter Aquitaine soils of the Weaber Plain may therefore demand shorter row lengths.

The farm unit layout outlined in Figure 3.2 has been developed using the above principles, although it is recognised that some adjustment to the farm units may be made at the detailed design phase as further data are gathered.

Farm development would initially consist of the clearing of vegetation by burning to remove any grass cover. This would be followed by bulldozing to remove the generally sparse tree cover that occurs on the black-soil plains. The felled trees would be chipped to provide mulch for use in rehabilitation or pushed up into windrows and burnt. Removal of vegetation would also include the removal of roots and stumps by a combination of grubbing by bulldozers and mechanised pinwheel rakes, followed by hand-picking if necessary. The farm area would then be ploughed using heavy disc ploughs, and minor surface irregularities would be removed by towing a float board over the surface. On completion of the above activities, the land would be surveyed for level on a maximum interval spacing of 50 m. The level information would then be used by designers to optimise the datum and gradient of the farm units to optimise the soil cut-and-fill balance.

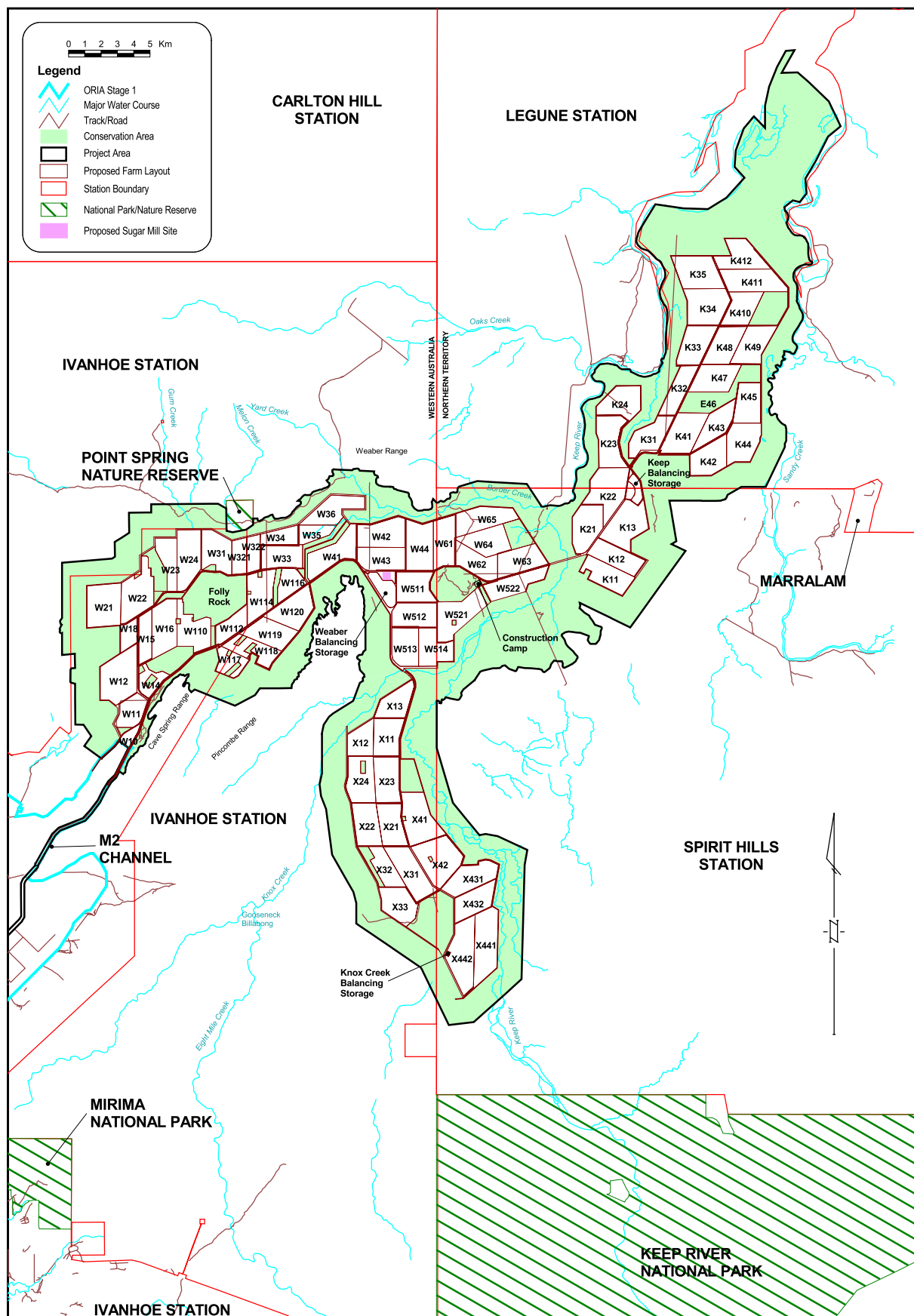


Figure 3.2 Farm Unit Layout

Land-levelling activities would follow shortly after design, using box scrapers towed behind large tractors and possibly with some final trimming using graders. As accuracy is an important feature of land-levelling activities, the levelling equipment would be guided by field laser. Farm development would then proceed with the construction of access roads, head ditches, tailwater return systems and stormwater drainage outlets. The water management components of the on-farm infrastructure are described further in Section 3.3. The standard proposed for the Wesfarmers–Marubeni corporate farm is for roads to be formed from the *in situ* black soil. Whilst access on these roads would be restricted during the wet season, the need for vehicle access around the farm during the wet season is expected to be minimal.

3.2.2 Ground preparation and planting

Ground preparation prior to planting would generally involve spraying with a herbicide such as glyphosate for the control of weeds, followed by cultivation to achieve an appropriate seed bed depth and tilth suitable for planting.

Sugarcane is grown from seed cane derived from the previous season's crop. This seed cane may be in the form of entire stalks or stalks chopped into smaller sections called billets. The seed cane is buried in rows and germination of the new plants occurs at the 'eyes' located at the nodes along the stalk.

It is envisaged that the Project would utilise modern planting machines that would combine the several required operations in one pass, including furrow-forming, fertiliser application, placement of the billets or stalks in the furrow, closing of the furrow and pressing of the soil on to the cane 'set'.

Section 3.4 describes the likely fertiliser and farm chemical requirements of the crop.

Planting of new sugarcane crops would depend on the cropping strategy adopted, but it is envisaged that replanting would be required every three to four years in the proposed development. In the intervening years, ratoon crops would be grown from the regrowth from the plant rootstock remaining following harvesting. Cultivation requirements for the ratoon crops would be kept to a minimum, and where necessary involve:

- cultivation of the inter-row;
- fertiliser application;
- weed control using a contact herbicide such as paraquat, or a pre-emergence herbicide, or by mechanical cultivation.

3.2.3 Sugarcane harvesting

Sugarcane harvesting operations would be similar to the methods being utilised in ORIA Stage 1. All cane-harvesting operations would take place during the dry season (April to November) and be scheduled to provide a continuous supply of cane to the raw-sugar mill.

Sugarcane harvesting would involve the following operations:

- cessation of irrigation to allow the farm block to dry out sufficiently to allow access by harvesting equipment;

- burning of the crop immediately prior to harvest. Burning operations would generally be undertaken at night. Burning is required to reduce the amount of trash associated with the cane at harvest, and it also confers other benefits such as the destruction of pests;
- harvesting of the cane using mechanised harvesters that remove the tops and remaining trash and cut the cane stalks into billets. The harvesters would load the billets directly into haulout vehicles;
- transfer of the sugarcane billets from haulout vehicles into road trailers for transport to the mill (Section 3.7);
- tagging of all loads to allow the mill to assess the quantity and quality of cane and the sugar content of each load.

It is generally believed that green-cane harvesting, which avoids the need to burn the crop prior to harvesting, would not be suitable for the ORIA. Currently some 60% of the sugarcane crop in Queensland and New South Wales is harvested using green-cane techniques and the proportion has been increasing steadily over recent years. However, in the Burdekin District of Queensland, which has similar cane yields and irrigation systems to Ord Stage 1, less than 5% of the crop in 1997 was harvested using green-cane techniques (Bureau of Sugar Experiment Stations 1998). As for the Burdekin District, the main reason preventing adoption of green-cane harvesting in Ord Stage 1 is that the sugarcane has particularly high trash levels and the residual trash blanket would interfere with the efficiency of the flood irrigation system. Green-cane harvesting is also slower and more costly than harvesting of burnt cane and results in higher trash levels being delivered to the mill.

3.2.4 Farm management

Certain management constraints would apply to farms within the Project Area. These would include the timing of the harvest to maintain continuous sugar production at the sugar mill, and the honouring of environmental commitments made in this ERMP/draft EIS, and any Ministerial Conditions that may apply to the Project. Wesfarmers–Marubeni and the Water Corporation would prepare an EMP for the Project upon receipt of environmental approval. The EMP would incorporate all the requirements of the commitments and conditions that apply to the Project and be prepared in consultation with the DEP, the DLPE and other relevant regulatory authorities.

Compliance with the EMP would be mandatory for all landowners and occupiers within the Project Area.

3.2.5 Sugarcane research and development

To maximise long-term sugar yields, a fully resourced and funded research and development programme would be established by Wesfarmers–Marubeni.

Core research programmes would include:

- the introduction/evaluation of new cane varieties
- plant nutrition
- pest and disease control

- weed control
- farming systems related to soil and water conservation.

Small-scale plot trials may be performed at the existing research station at the Frank Wise Institute, given the existing investment in equipment and irrigation facilities for small-scale plot trials at that facility. Trials conducted at the research station may include variety testing, and pest and weed control.

Larger scale trials would also be conducted on the Wesfarmers–Marubeni corporate farm, to more accurately reflect the soil conditions of the Project Area. An area of approximately 80 ha would be set aside for this purpose.

Relevant results from the research and development programme would be incorporated into updates of the EMP.

3.3 ON-FARM WATER MANAGEMENT

3.3.1 Crop water requirements

Estimates of the in-field water requirements for the major crops likely to be grown on the black soil areas of the ORIA are set out in Table 3.2.

Table 3.2 Estimated in-field water requirements for irrigated crops in the ORIA

Month	Monthly water requirement (ML/ha)						
	Cotton (furrow)*	Sugarcane (furrow)*	Leucaena (furrow)*	Forage maize (furrow)* ^H	Hybrid seed sorghum (furrow)*	Hybrid seed sunflower (furrow)*	Chick pea (furrow)*
January	–	0.29	1.00	–	–	–	–
February	–	–	0	–	–	–	–
March	–	0.67	1.00	–	–	–	–
April	0.94	1.43	2.00	1.00	1.50	1.50	1.50
May	1.41	1.96	2.00	0.75	1.10	1.10	1.00
June	1.41	1.72	1.00	2.25	1.20	1.60	1.40
July	1.88	1.80	1.50	2.25	1.95	2.00	1.40
August	2.82	2.32	1.50	0.75	1.30	0.50	1.40
September	2.82	2.57	2.00	–	–	–	–
October	–	2.24	2.00	–	–	–	–
November	–	1.88	2.00	–	–	–	–
December	–	1.21	2.00	–	–	–	–
Total	11.28	18.09	18.00	7.00	7.05	6.70	6.70

* Seventy-five per cent application efficiency, typical of flood irrigation in the ORIA, assumed.

^HEstablished leucaena undersown with pasture.

Source: Sherrard 1994

Cotton has the highest monthly water requirement of 2.82 ML/ha in August and September, closely followed by sugarcane, which has a requirement of 2.57 ML/ha in September. The peak demand for both crops therefore occurs late in the dry season when significant rainfall is rare. Sugarcane has the highest estimated annual water requirement of 18.09 ML/ha, closely followed by established leucaena undersown with pasture.

The 1-in-5-year recurrence interval monthly evaporation is approximately 10% above the average evaporation rate, and during these times the peak water requirements could be 10% above those shown in Table 3.2. For cotton this peak monthly water requirement is therefore about 3.10 ML/ha.

Precision farm water management techniques would be developed for the Project Area and their adoption would be required under the proposed Environmental Management Plan. It is anticipated that these techniques would be based upon measurement of actual crop water use in the soil profile to determine the timing and magnitude of irrigation applications. For example, current planning assumes an application of about 90 mm of irrigation water following an estimated evapotranspiration loss of the same value in the crop.

3.3.2 Tailwater management systems

All farms in the Project Area would be developed with irrigation tailwater management systems. Irrigation tailwater is the water that would leave the bottom of the furrows during watering. Irrigation tailwater is unavoidable if uniform water application to the crop is desired.

A conceptual tailwater management system proposed for use in the Project Area is outlined in Figure 3.3 and would consist of the following elements:

- a tailwater ditch that would collect tailwater from the furrows and deliver tailwater to a tailwater dam;
- tailwater dams. The volume of these dams would be optimised during detail design with the objective being to minimise off-farm discharges of irrigation tailwater during the dry season. As a minimum, the tailwater dam capacity would be sufficient to provide the specified first-flush stormwater retention capacity (Section 5.5.2 refers) for the Project—12 mm of rainfall runoff for sugarcane farms and 25 mm of rainfall runoff from other farms;
- tailwater return pumps and pipelines that would return irrigation tailwater to the farm head ditch or to other intermediate points in the farm irrigation system for application to the crop. The tailwater return pumps would be configured to operate at partial filling of the dam, thereby reducing the volume of tailwater requiring storage.

Observations indicate that some 25–50% of the applied water in ORIA Stage 1 is discharged to the drainage system as tailwater. The farms on ORIA Stage 1 were not developed with tailwater return systems as the merits of tailwater return systems were not widely known at the time of development.

3.3.3 Crop drainage requirements

Drainage requirements would be largely dependent upon the crops grown, as different crops have different tolerance levels to flooding. Sugarcane is a crop that is tolerant to flooding:

research in Queensland has shown that sugar yields are not depressed by up to 72 hours' inundation and that yield depressions by longer periods of inundation is insufficient to justify significant expenditure on drainage.

For crops other than sugarcane it is usually sufficient to adopt a design criterion that aims to remove water from the 'design storm' in 48 hours. The design storm is generally a storm in duration of 48 hours and a recurrence interval of five years. In Kununurra this equates to a storm with a rainfall intensity of 3.7 mm/h.

3.3.4 Collection and discharge of stormwater

A portion of water from any rainfall event would infiltrate into the soil profile, with the magnitude of this proportion dependent upon the intensity and duration of the rainfall event and the moisture content of the soil immediately prior to the rainfall event. Thus, low-intensity or short-duration rainfall events may produce little or no runoff from farm areas that are not saturated. The converse is also true, with a high proportion of runoff expected from high-intensity or long-duration storms, particularly from farm areas that were either irrigated or subject to a rainfall event immediately prior to the storm occurring.

Rainfall runoff from the cropped areas would be collected by the irrigation furrows and the tailwater collection system. As discussed in Section 3.3.2, the tailwater storage dams would be designed to act as first-flush collection systems for stormwater. First-flush stormwater is likely to contain higher concentrations of sediment, organic matter, fertiliser and other farm chemicals than stormwater arising later in the rainfall event or subsequent rainfall events. Runoff would be retained in the tailwater management system for subsequent use as irrigation water. The remainder would discharge to the drainage infrastructure system (described in Section 3.5.2) and then either to the Keep River or to Sandy Creek.

3.4 FARM FERTILISERS, CHEMICALS AND THEIR USE

The predominant crop to be grown on the Project Area would be sugarcane. Experience with this crop in ORIA Stage 1 has shown that it has a low requirement for pesticides, in relation to other crops to grow successfully. The following sections describe the likely farm chemical and fertiliser use for sugarcane and other crops that may potentially be grown within the Project Area.

3.4.1 Sugarcane

The likely requirements for fertiliser for sugarcane grown within the Project Area, are as follows:

- *urea*; applied at an indicative rate of 400 hg/ha/a to provide a source of nitrogen
- *diammonium phosphate (DAP)*; applied at an indicative rate of 200 kg/ha/a to provide a source of nitrogen and phosphorus.

Fertilisers would be applied at planting and at some three to four weeks after planting. Ratoon crops would also be fertilised following the previous harvest.

Weed control would also be required for sugarcane and this would be provided by the application of herbicides such as glyphosate.

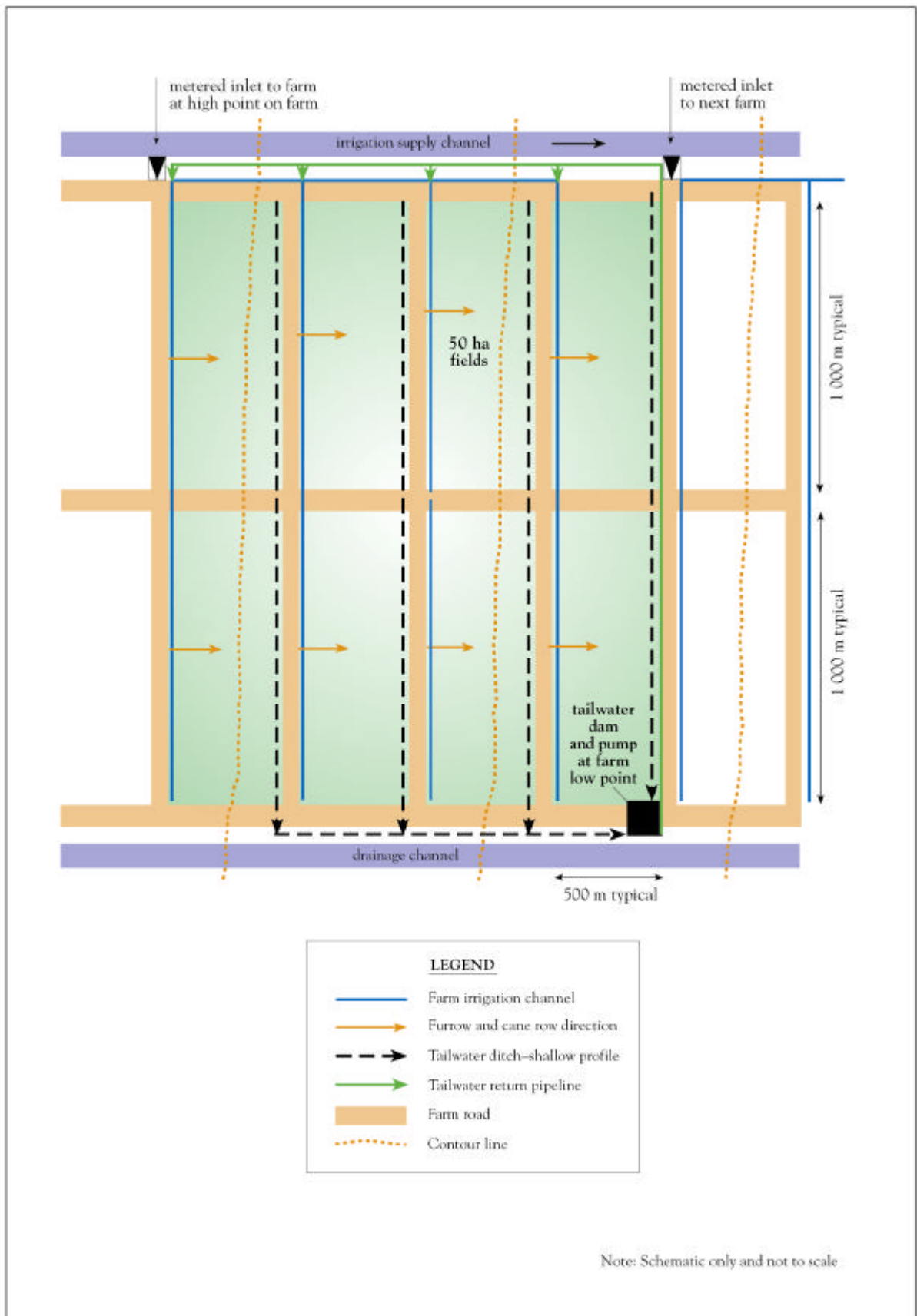


Figure 3.3 Conceptual tailwater return system

The primary means of managing diseases in sugarcane, such as the fungus Sugarcane Smut which was recently discovered in ORIA Stage 1, is to plant with varieties known to be naturally resistant to such diseases. Hence, as confirmed by experience with ORIA Stage 1, it is likely that minimal usage of pesticides or fungicides would be required by the sugarcane. Usage may involve the occasional application of a fungicide, such as Prochloraz, at the time of planting the seed cane.

3.4.2 Other crops

Farm chemical and fertiliser requirements for crops other than sugarcane would depend upon the actual crops under cultivation. Section 2.4.1 outlines the agricultural chemicals currently used in ORIA Stage 1. It is anticipated that a similar range of chemicals would be used on the land farmed by independent farmers within the Project Area.

In accordance with current practice in ORIA Stage 1, application of farm fertilisers and chemicals would involve direct application of fertiliser to the crop root zone and tractor-drawn boom-spraying and aerial-spraying in the case of herbicides and pesticides. Regimes of chemical and fertilizer usage in terms of type, timing and method of application, would be incorporated into the EMP to be developed for the Project Area (Section 3.2.4). These restrictions would as a minimum include:

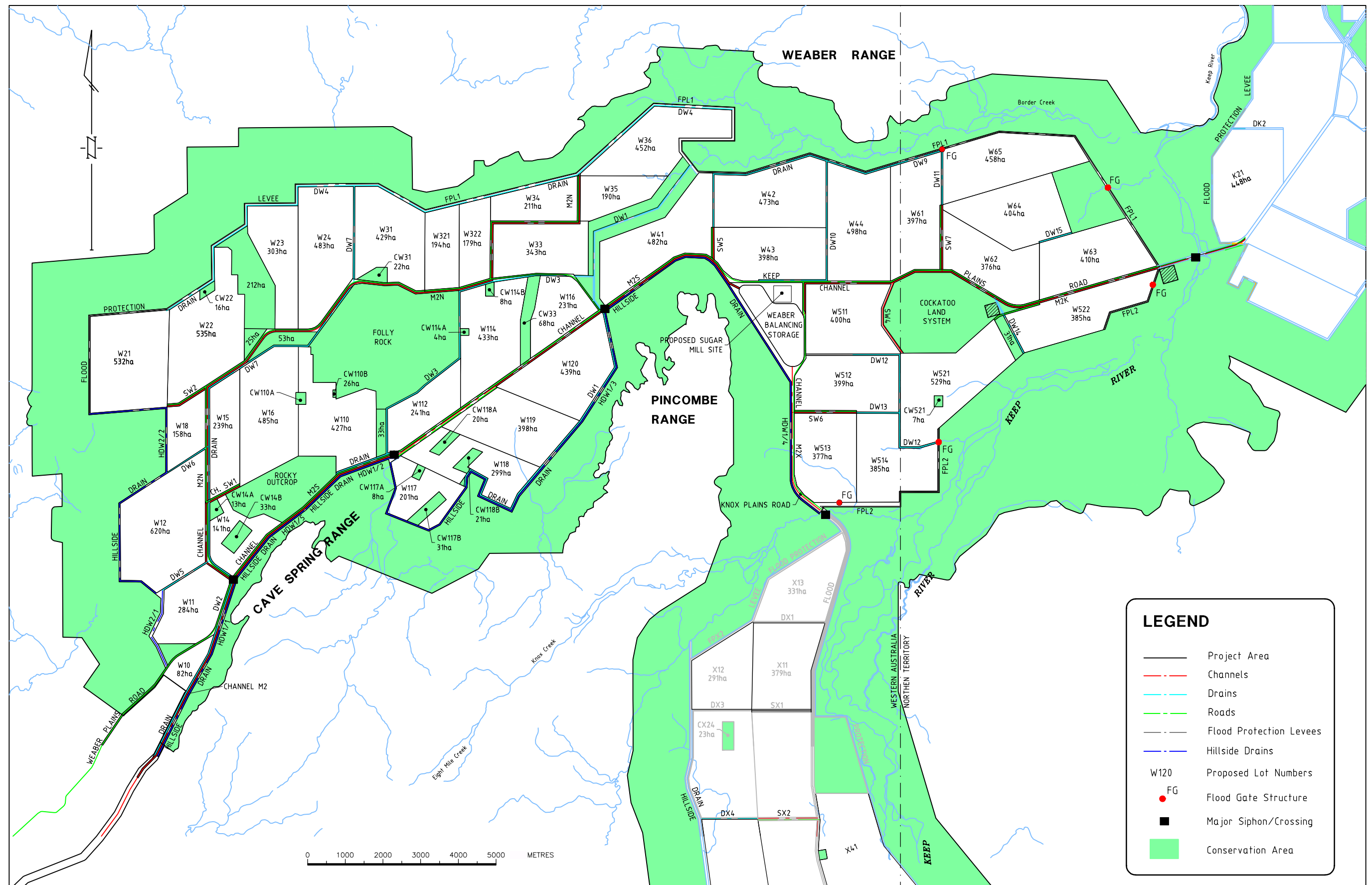
- pesticide application in accordance with the annual spray calendar prepared for the ORIA;
- the use only of chemicals that are approved by the Governments of Western Australia and the Northern Territory;
- the successful completion of training for farm staff required to spray chemicals;
- commercial spray operators being required to be fully accredited under a national standards system;
- a ban on the use of endosulfan during the wet season (November to March) and at other times when the crop areas have free-standing water in either the furrows or tail drains;
- application of endosulfan to comply with the NRA review recommendations (Section 2.3.1 refers), and substitution of more benign insecticides for endosulfan wherever possible.

3.5 IRRIGATION, DRAINAGE AND FLOOD PROTECTION INFRASTRUCTURE

The Water Corporation would be responsible for provision of the entire off-farm irrigation, drainage and flood protection infrastructure required by the proposed development. The following sections describe the works proposed.

3.5.1 Irrigation infrastructure

The water supply and storage system for the Project are illustrated in Figures 3.4 to 3.6.



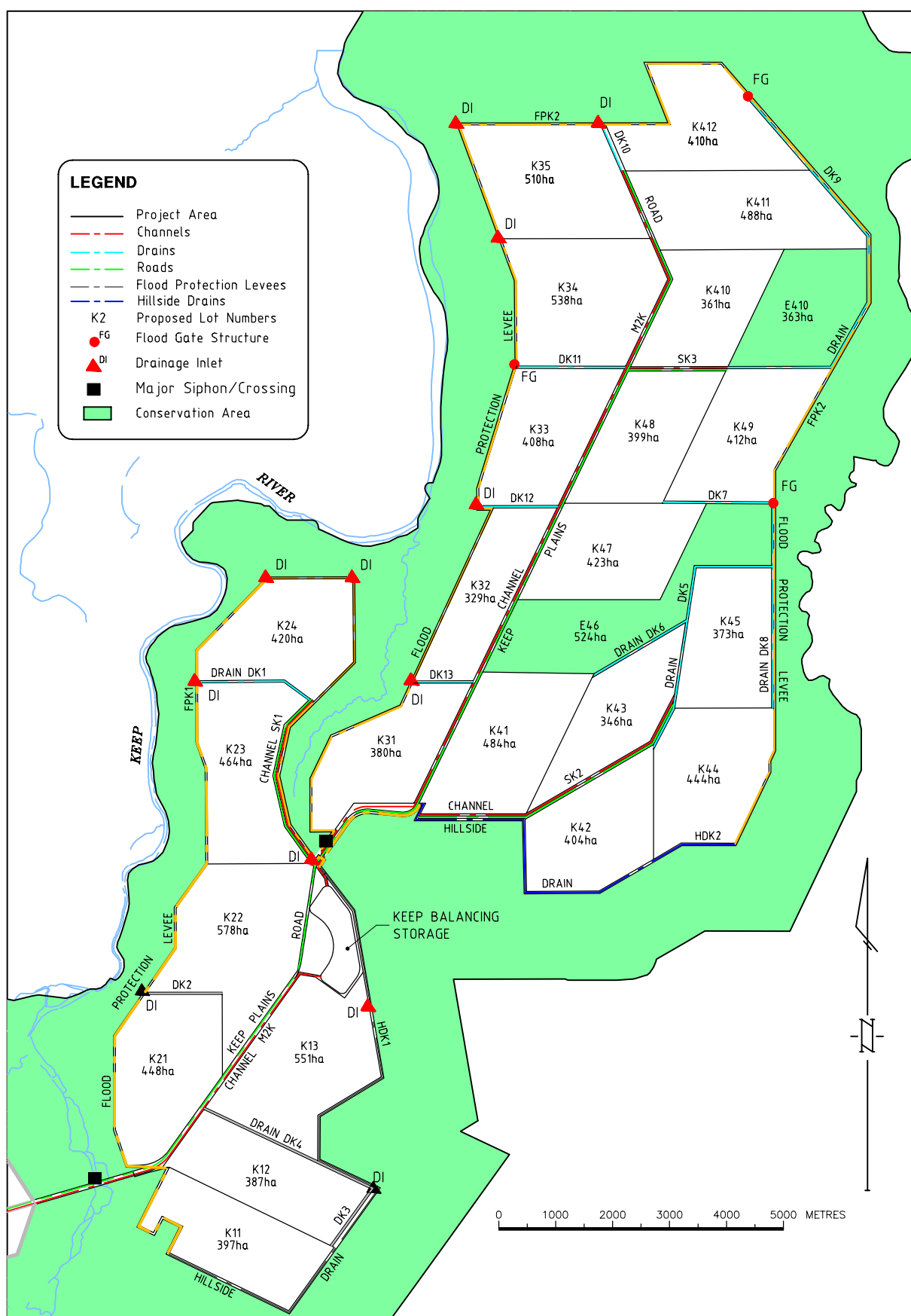


Figure 3.5 Infrastructure - Keep River Plain

Main supply channels

Irrigation water supply for the Weaber Plain, Knox Creek Plain and Keep River Plain would be sourced from Lake Argyle via the Ord River and Lake Kununurra. Irrigation water would be gravity fed from Lake Kununurra to the Project Area via a purpose-built channel, known as the M2 Channel.

The M2 Channel intake would be located adjacent to the existing M1 Channel intake structure on the north bank of Lake Kununurra. The proposed M2 Channel would be aligned parallel and east of the M1 Channel for some 24 km, to the point where the M1 channel terminates at the southern end of Cave Spring Gap.

Through Cave Spring Gap, the M2 channel alignment would be along the base of Cave Spring Range. On the Weaber Plain, the M2 channel would bifurcate to form the M2N Channel and the M2S Channel. The former would service the northern portion of the Weaber plain and terminate at the supply point to farm block W36, and the latter would service the southern portion, and terminate at the Weaber Balancing Storage.

From the Weaber Balancing Storage, main supply channels would be constructed to supply the Keep River Plain, including the eastern portion of the Weaber Plain, and the Knox Creek Plain. The former would be known as the M2K Channel, and the latter as the M2X Channel.

The supply channels would be open excavations with sloping sides (Figure 3.7). The soil from the excavation would be used to form compacted banks on each side of the channels, and the banks would be around 4–5 m wide at their crest. Typically, the channel water levels would be above natural surface level. At some locations, however, the water level would be below the natural surface water. Bed widths (the channel bases) would be between 4 m and 14 m. Compacted clay channel lining would be provided in locations where the channel would be constructed in more permeable soils, and in these locations. The channel lining would be at least 0.5 m thick over the bed and the lower 1–2 m of the channel batters.

Surplus water in the M1 Channel currently discharges via a drain onto the Weaber Plain. This practice would be discontinued if the proposed development were to proceed and any surplus water would remain within the ORIA Stage 1 water system.

Secondary supply channels

Secondary supply channels would be required in the Weaber Plain to service farming units that cannot be supplied directly from the main supply channels. The channel profiles of these laterals would be similar to those of the main supply channels yet smaller, due to the lower volumes of water to be conveyed.

Balancing storage dams

Three balancing storage dams are proposed:

- the Weaber Plain Balancing Storage Dam—a dam with a surface area of 185 ha and an operating volume of 4.07 GL, located on the Weaber Plain at the intersection of the M2S Channel, M2K Channel and M2X Channel;
- the Keep River Plain Balancing Storage Dam—a dam of 85 ha surface area and an operating volume of 1.5 GL, located on the Keep River Plain;

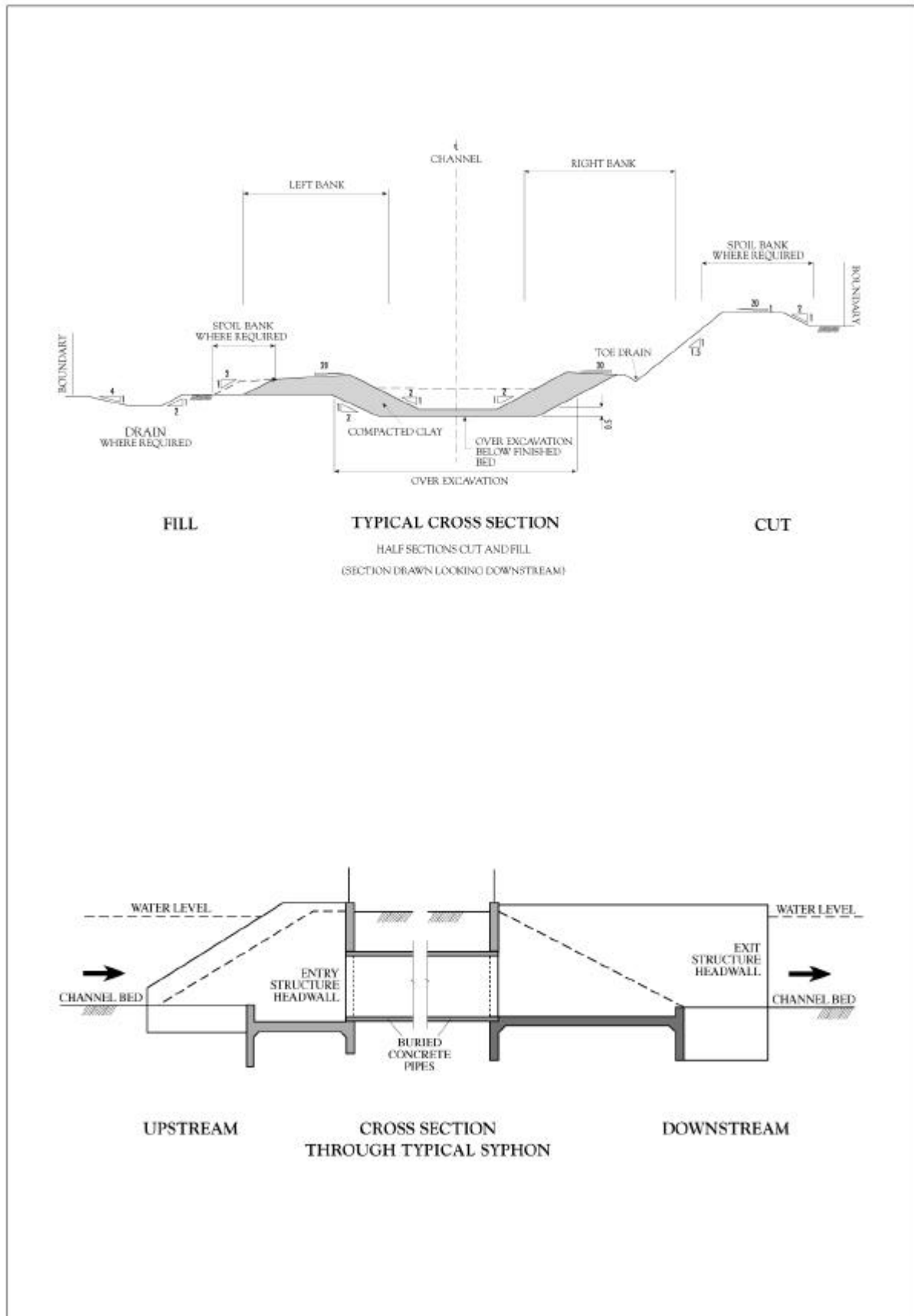


Figure 3.7 Typical supply channel cross section and siphon structure

- the Knox Creek Plain Balancing Storage Dam—a dam with a surface area of 6 ha and an operating volume of 16 ML, located at the southern extremity of the Knox Creek Plain.

The balancing storage dams would facilitate operation of the irrigation supply system, particularly in meeting peak demands or in providing buffer storage at times other than normal operating conditions. In doing so they would reduce significantly the requirement to discharge water to the drainage system from the supply channels, as is currently the case in ORIA Stage 1.

The balancing storage dams would consist of a clay-lined perimeter embankment with an internal lining of stone riprap to prevent erosion from wave action. They would also include entry and exit structures with remote controlled gates.

Control System

The control system for the irrigation infrastructure in ORIA Stage 1 relies upon manual operation of control gates. This is in contrast to the system proposed for the Project, which would be based upon a modern remote control system designed to maximise efficiency of water distribution while minimising operating costs. The control system would utilise Supervisory, Control and Data Acquisition (SCADA) technology to provide a radio link between activators on control structures and sensors monitoring flow conditions in the channels, with a centralised control facility. The SCADA system would allow one operator to concurrently control a number of different parts of the system, with consequent productivity improvements over a manual system.

Other significant irrigation infrastructure items

Typical structures on irrigation channels would include:

- channel-flow regulating and measuring structures
- lateral channel off-take structures
- channel overflow and drainage facilities
- pumping stations
- channel siphons
- channel bridge and culvert road crossings.

There are seventeen major inverted siphon structures proposed for the entire Project. The siphons (Figure 3.7 refers) consist of multiple buried pipes to convey water beneath natural features such as riverbeds or constructed features such as roads or drains. They have significant intake and outlet structures, but are generally preferred to bridges or other options on economic grounds. Significant siphon structures include:

- the Knox Creek Siphon on the M2X Channel. This is proposed as a twin, 1,800 mm diameter pipe structure some 120 m long. It would provide a facility for the M2X Channel to cross underneath the Knox Creek between the Weaber Plain and Knox Creek Plain areas;
- the Keep River Siphon on the M2K Channel. This is proposed as a twin-barrel, 1,800 mm diameter pipe structure some 500 m long. It would have a similar design to the

Knox Creek Siphon and would provide a facility for the M2K Channel to cross underneath the Keep River between the Weaber Plain and the Keep River Plain;

- the Keep River Re-entrant Siphon on the M2K Channel (downstream of the Keep River Plain Balancing Storage Dam). This smaller structure, proposed as a twin-barrel, 1,800 mm diameter pipe structure some 120 m long, would convey the M2K Channel flows across and underneath a Keep River re-entrant creek.

3.5.2 Drainage infrastructure

The drainage system for the Project is shown in Figures 3.4 to 3.6. The system comprises a variety of open, excavated drains that would collect stormwater runoff from developed farming areas and local drainage from outside the farming areas. These open drains would be located along low points in such a way that they service each farm unit. Drains have been designed to exit the farming areas at the perimeter of the development via floodgates in the flood protection levees and discharge into natural drainage features.

Current planning is based upon the use of wider, shallower drains than were built in ORIA Stage 1. This approach would minimise seepage to groundwater by locating the channel inverts in the less permeable surface soils. Where deeper drains are required, the excavated surface of the drain would be compacted to minimise seepage. The drains would be constructed to a trapezoidal cross-section with the design flow level kept at or slightly below the natural surface.

The proposed destination of the greater part of the stormwater from the Weaber Plain is Border Creek, to the north, which in turn drains to the Keep River. The Knox Creek Plain would be drained to the Keep River, while the Keep River Plain would be drained to the Keep River and to Sandy Creek.

The Project has been designed so that drainage channels would only convey water during the wet season following rainfall events. At all other times the channels should be dry, and provide access corridors for native fauna within the Project Area.

Chapter 5 outlines surface water issues in relation to the proposed development, and Chapter 10 outlines the conservation corridors within the Project Area.

3.5.3 Flood protection infrastructure

Hillside drains would be developed at the perimeters of developed farmland to divert stormwater runoff from adjacent catchments (Figures 3.4 to 3.6). These structures would be embankments less than 3 m in height, combined with limited excavation to ensure continuous longitudinal drainage.

Farmland adjacent to significant waterways would be protected from flooding by levees (Figures 3.4 to 3.6). Intense rainfall in the region, and the fact that much of the proposed farmland would be flooded regularly under natural conditions, implies that a levee system would be essential for farm protection. Economic considerations indicate that levees could not be designed to protect against all flood events. The preliminary design has adopted a 4% annual probability of exceedence as a reasonable design criterion.

Flood protection levees would be earth embankments generally 1–3 m in height, with 2:1 side slopes and a 4 m crest width. Earth for the flood protection levees would generally be

obtained from excavations associated with construction of the drainage infrastructure and hillside drains. Borrow pits located alongside the flood protection levees may be required in some locations.

The flood protection levees would incorporate flood gate and drainage inlet structures that would allow the discharge of stormwater run-off from the developed area to be collected by the perimeter drainage channels.

3.6 OTHER INFRASTRUCTURE

3.6.1 Roads

The road system proposed for the development of the Weaber, Knox Creek and Keep River plains (Figures 3.4 to 3.6) would comprise:

- the Weaber Plain Road from the end of ORIA Stage 1 across the Weaber Plain to the Weaber Balancing Storage Dam;
- the Keep Plain Road from the Weaber Balancing Storage Dam eastwards across the Keep River and northwards through the central portion of the Keep Plain;
- the Knox Plain Road from Weaber Balancing Storage Dam, southwards across Knox Creek and through the centre of the Knox Creek Plain;
- roads in the northern Weaber Plain

Two significant waterway crossings would be required with this road system:

- a Knox Creek crossing—a low-level culvert crossing (embankment)
- a Keep River crossing—a low-level bridge or culvert crossing.

These stream crossings would provide access under all but peak flood conditions.

Public roads in the system would be two-way, and would have a total carriageway width of 6–7 m. They would have a sealed or gravelled surface, depending on traffic density. In addition, they would be provided with a wide, sealed shoulder where they are constructed over black-soil areas to reduce road maintenance.

Secondary roads, where required for access to the corporate farm, would be formed from black soil only and not sealed or surfaced with gravel. Accordingly, these roads would have limited use during the wet season.

The design and construction of roads within the Project Area would be to a standard suitable for use by large transport vehicles, including B-double semi-trailers and road trains.

3.6.2 Power

Power requirements within the Project Area during the processing season would be supplied predominately by the sugar mill, utilising bagasse (cane fibre) as fuel. During the non-processing season the power requirements of the mill, irrigation infrastructure, and on-farm purposes, would be supplied either by Western Power or local generating capacity. A power distribution system, using overhead transmission lines, would be developed for the Project.

Small power requirements throughout the proposed farm area may be provided by diesel motors or generating sets where it is not economical to extend the power distribution system.

3.6.3 Telecommunications

Telecommunication requirements for the Project would be provided by a combination of:

- extension of the digital mobile phone network from Kununurra to cover the Project Area;
- extension of the optical fibre network from Kununurra to the mill site;
- establishment of a two-way radio network for use by the corporate farm and by transport and harvesting contractors;
- establishment of a SCADA system for the remote control of irrigation infrastructure.

3.7 SUGAR-MILLING

3.7.1 Scope

The proposed Wesfarmers–Marubeni sugar mill has been sized, to have a crushing capacity of approximately 750 t of cane per hour, enabling a steady state annual sugarcane crush of approximately 3.2 Mt.

The preferred mill location (Figure 3.2) has been selected adjacent to the Weaber Balancing Storage Dam, and at the centroid of the proposed plantation development.

Based upon local sugarcane characteristics and the projected mill efficiency, approximately 1 t of raw sugar would be produced for every 8 t of sugarcane processed, and 1 t of molasses would be produced for every 20 t of sugarcane processed.

A natural production ramp-up in the start-up phase would be provided by the planned development of the corporate farm as outlined in Table 3.3. Peak production of 3.3 Mt would occur in 2005 but that production would stabilise at approximately 3.2 Mt in the steady state.

Table 3.3 Sugar-mill crushing volume

Rate	Year			
	2003	2004	2005	Steady state
Cane supplied to mill (Mt)	1.3	2.5	3.3	3.2

The mill would be designed for 24-hour operation and would be provided with a high level of automation in order to maximise efficiency.

3.7.2 Process description

The function of the sugar mill is to recover from sugarcane the maximum practicable quantity of sucrose, and process the sucrose into raw sugar of a specified quality. The mill would operate during a cane-harvesting season of approximately seven months' duration. During the non-processing season, the processing plant would be overhauled in preparation for the following crushing season.

The milling process described further below is illustrated in the simplified flow diagram in Figure 3.8.

Sugarcane would be delivered to the mill by road transport and, after weighing of the loaded vehicles, the cane would be tipped into a cane-carrier. The empty vehicle would then be weighed to determine the weight of sugarcane delivered.

The cane-carrier would deliver the sugarcane to a cane conveyor which feeds a shredder. The function of the shredder is to rupture a high percentage of the cane-stalk cells, thereby liberating the stored sugar. The shredded cane would then be fed to the first crushing mill.

In the crushing mills, the shredded cane would be squeezed between mill rollers to extract the cane juice. The milling train would consist of successive mills, each comprising pressure feed rollers and juice extraction rollers. Between successive mills, the crushed cane would be immersed in water to dilute the juice remaining in the cane fibre. The cane fibre would then be allowed to drain before passing into the following mill for further juice extraction.

Cane fibre from the final crushing mill, which is called bagasse, would be conveyed to storage and thence to the boiler to be burned as fuel for the generation of steam. High-pressure steam would be used in the various turbines that drive process equipment and in the electricity generators in the mill's power station. The low-pressure steam issuing from the turbines would provide the heat energy for process heating requirements.

Processing of the juice collected from the crushing mills would involve heating, followed by addition of lime and synthetic flocculant, and then clarification. In the clarifiers the mud solids and lime precipitates would settle out and be collected for further treatment by vacuum mud filtration. The filtrate (sweet water) would be returned to the process.

The clear juice from the clarifier would be passed through evaporators where it would be concentrated to about 65% soluble solids by evaporation of water. The syrup thus produced would then pass to vacuum pans. Each vacuum pan would boil the syrup under a vacuum in the presence of a slurry of seed crystals. After a period of crystal growth, the resulting 'massecuite' would be discharged from the pan into a receiving vessel. The 'mother syrup' (molasses) would be separated from the raw-sugar crystals by centrifuging and recycled to the vacuum pans station for further recovery of sugar. The raw-sugar crystals would pass to the sugar drier and would then be cooled in a counter current flow of air. The dried raw sugar would then be conveyed through a weigher to the mill storage and truck loading facility.

The syrup from which it is uneconomic to extract further sugar is 'final molasses', which would be weighed, cooled and pumped to the mill storage tanks.

All power requirements for the mill during normal operations would be provided from burning the bagasse remaining after processing of the cane. At other times, such as during annual start-up and in the off season, power would be obtained either from local generating capacity or from Western Power.

Apart from sugarcane, the major process inputs would be lime and small volumes of caustic and specialty chemicals, such as synthetic flocculants. Lime would be used to precipitate impurities from cane juice and the synthetic flocculents (usually food-grade polyacrylamides) would be used to assist in the clarification of heated, limed cane juice. Caustic soda solution would be used for cleaning heating surfaces in mill evaporators.

An additional, but relatively minor, chemical input would be that associated with pretreatment of boiler make-up water. Typical chemicals used for feedwater treatment are carbonates, sulphates and sulphites of sodium, polyphosphates and an anti-foam preparation. These chemicals would be discharged from the boilers in blow-down water.

3.7.3 Effluents and emissions

Atmospheric emissions would consist of water vapour from the process equipment and the normal products of combustion from the bagasse and fuel-oil-fired boiler.

The boiler would operate continuously for about seven months of each year. Emissions from the boiler would be passed through a scrubber to achieve a maximum particulate discharge of 32 kg/h from the 40 m high chimney. The total gas volume discharged via the chimney would be 420 m³/h at 45°C with a density of 0.832 kg/m³. This equates to a particulate emission level of less than 0.12 g/Nm³. Bagasse firing would be a complete combustion process with excess oxygen available at all times. Carbon monoxide levels would therefore be extremely low.

The use of fuel oil would be necessary during boiler start-up conditions. The fuel oil would typically contain 0.7% sulphur, and the discharge gases are expected to contain 300 ppm of sulphur dioxide, 200 ppm of oxides of nitrogen and less than 200 mg/Nm³ of carbon monoxide.

Water vapour would be given off by process cooling towers. This vapour would have no contamination and would be pure water. Steam at temperatures ranging from 120°C to 400°C would also be emitted to the atmosphere on occasions.

A diesel generator would be provided at the mill to operate during the milling season on a stand-by basis only. When this generator is operational, exhaust gas would be emitted to the atmosphere at a rate of 95 m³/h, and contain 37 g/Nm³ of oxides of nitrogen, 11 g/Nm³ of carbon monoxide and 1.25 g/Nm³ of hydrocarbons.

Liquid discharges from the mill would predominantly consist of cooling water and small quantities of process effluent treated as described below.

Cooling water sourced from the irrigation infrastructure would be used at a rate of approximately 12,000 m³/h to condense the vapour generated in the vacuum pans. The cooling water would be discharged into the irrigation infrastructure, downstream of the intake point. The discharged cooling water would have no additional contamination, and would be approximately 3°C warmer than the intake water.

Process effluent would arise at a flow rate of about 200 m³/h and at a biological oxygen demand (BOD) level of 1,500 mg/L (mainly due to sucrose). The process effluent would be treated in a biological treatment plant combining activated sludge and anaerobic processes. The treated effluent, with a BOD level of less than 20 mg/L, may be used as irrigation water directly on to canefields near to the mill.

Blow-down water from the boiler would produce an effluent stream of about 6L/s during mill operations. This water would have negligible BOD, but would contain total dissolved solids (TDS) up to a concentration of 200 mg/L. The dissolved solids would arise from naturally occurring salts in the boiler make-up water and from the boiler feedwater chemicals collected from the boiler combustion chambers and from the boiler flue gases by an

emission-cleaning system. The boiler blow-down would be combined with the process effluent for disposal.

Ash from the boiler would comprise the unburned residue of bagasse, generally about 90% inorganic matter and 10% carbon. The levels of the ash in bagasse would be variable and depend largely on the amount of field soil entering the mill with the cane. About 20 t/h of ash (with a 50% moisture content) would be produced by the boiler, with the major constituents expected to be silica, alumina, iron oxide, potash and lime. Silica should represent 90% of the solid mass, and the percentage of lime would be expected to be about 1%.

Disposal of the ash would be effected by spreading on to canefields. The ash mixture would act both as a soil conditioner and as a fertiliser and should be beneficial to the soils of the Project Area. All that would be returned to the soil by spreading the mill mud and ash would be the minerals extracted by the cane from the soil and soil itself.

3.8 PROCESSING OF OTHER CROPS

Crops other than sugarcane may be propagated on the land farmed by independent farmers within the Project Area. It is anticipated that any further processing of these crops would occur at existing facilities located within ORIA Stage 1.

3.9 MATERIALS HANDLING AND TRANSPORT

3.9.1 Sugarcane transport

Transport of cane would be carried out using purpose-designed road transport vehicles with a payload of approximately 100 t. In the steady state, sugarcane supply to the mill would be 3.2 Mt/a, and approximately eight trucks would arrive at the mill every hour over a 24-hour period, seven days a week for seven months of the year. The following measures would be adopted with respect to cane haulage:

- Trucks would be operated and maintained to meet the requirements of relevant noise abatement legislation.
- Public roads would be designed to the appropriate national road design standards in order to provide an acceptable level of safety for the cane transport operations and any other road users.

3.9.2 Farm requirements

Bulk farm inputs would predominantly comprise fertilisers including urea and DAP. Fertilisers would be transported in bulk form in semi-trailers to dedicated storage facilities, established in each of the three plains. Fertilizers would then be transferred by closed screw conveyors directly into field distribution vehicles.

Other farm requirements would include:

- diesel fuel for agricultural machinery and generators
- herbicides for use over the whole Project Area
- other pesticides for use on farms not dedicated to sugarcane.

All of the above farm requirements would be transported and stored in accordance with regulatory requirements, including impervious bunding of storage areas where appropriate.

3.9.3 Products

Raw-sugar and molasses transport from the mill to the port of Wyndham would be carried out over the processing season in purpose-built road transport vehicles with a payload of approximately 90 t. On this basis, approximately thirty vehicle movements per day are anticipated for product transport from the Project Area. At this stage, it has been assumed that transport from the Project Area to Wyndham would be via the existing Kununurra–Wyndham road.

The main product storage facilities in relation to the proposed development would be developed adjacent to the Wyndham wharf (Figure 3.9), with a nominal capacity of 180,000 t for raw sugar and 75,000 t for molasses. Development of these storage facilities would require the reclamation of a portion of unvegetated mud flat adjacent to the southern section of the Wyndham wharf access road.



Figure 3.9 New storage facilities within the Wyndham Port

A conveyor system would be developed to move raw sugar from the storage shed to the existing shiploader. A pressurised pipe would take molasses from the storage tank to the wharf.

Shipment sizes from the port of Wyndham would typically be in 20,000 t vessels. On this basis, in the steady state, twenty-eight shipments would be required annually, implying shipments from Wyndham every thirteen days.

3.10 CONSTRUCTION ISSUES

The current construction schedule for the irrigation infrastructure, sugar mill, port facilities and other infrastructure allows for staged development occurring over three years (Figure 3.1 refers). With the exception of the sugar mill, all earthworks and major construction would take place during dry seasons and be planned in such a way that all necessary flood protection levees and drainage systems would be in place prior to the onset of the wet seasons. The phased development would commence on the Weaber Plain, then proceed on the Keep River Plain and finally the Knox Creek Plain. The mill would be constructed over a period of two years and receive the first cane for processing in 2003.

Prior to the construction of the irrigation infrastructure, the land corridors for these facilities would be cleared of any existing vegetation and grubbed to remove roots. In areas where corridor widths are significantly greater than those required for construction, only the sections necessary for construction and future maintenance purposes would be cleared. The uncleared sections of the corridors would be managed as part of the conservation reserve system for the Project.

Construction of roads and the irrigation infrastructure would require access to local sources of suitable clay, sand and gravel material. Borrow pits would be selected in accordance with Aboriginal cultural and heritage considerations of the land and operated as far as practicable with a view to minimising erosion, damage to surrounding vegetation and visual impact. Once construction is completed, areas no longer required would be rehabilitated by a combination of contouring, slope stabilisation, topsoil spreading and seeding.

It has been estimated that the total combined workforce for the construction phase would peak at 650. A construction camp would be established within the Project Area adjacent to the existing homestead of Spirit Hills Station in the Northern Territory (Figure 3.2 refers). Upon completion of the construction period, the construction camp may be modified to accommodate seasonal workers.

Potable water would be provided for the construction camp from purpose-drilled bores. The bores would be approved by either the Water and Rivers Commission of Western Australia or the Department of Lands, Planning & Environment, depending upon their location.

Sewage and refuse from the camp would be treated and disposed of in a manner approved by the relevant public health authorities of the Northern Territory.

Few construction-related environmental issues are envisaged due to the remoteness of the Project Area from residential areas. An exception relates to the proximity of a section of the proposed M2 Channel, which in some areas is within 300 m of residences. The following measures would be employed at these locations to minimise nuisance from construction equipment:

- Construction activities would be restricted to daylight hours.

- Prior to use, all equipment would be checked to ensure that silencing equipment had been fitted and was in good working order.

Local residents would be advised of the nature of the activities to be undertaken and of their duration, particularly if blasting were required to remove rock.

3.11 ENVIRONMENTAL MANAGEMENT AND MONITORING SYSTEM

A comprehensive environmental management and monitoring system would be developed and implemented as part of the Project. In summary this comprises:

- the retention of areas of existing vegetation in conservation areas and linkages (corridors) between these areas where this is appropriate (Chapter 10 refers). Monitoring within the conservation areas would include indicator species of environmental health and possible impacts from the Project such as the presence of weeds;
- a surface-water monitoring system designed to gather data on possible impact from the Project (Chapter 5 refers). This monitoring would include water quality measurement, including nutrients and pesticides, flow measurements and monitoring of aquatic flora and fauna species selected to be indicators of environmental health;
- groundwater monitoring for both level and quality via a network of monitoring bores located within the Project Area. The possibility of the need for future groundwater management is recognised and this may take the form of abstraction bores and a collector pipework system. Collected groundwater would either be used as irrigation water or discharged to the estuarine portion of the Keep River and Sandy Creek, depending upon the water quality. This system is described further in Chapter 6.

An important issue for environmental management is the allocation of responsibilities for the various activities identified in this ERMP/draft EIS and any unforeseen measures that may be required in future. An environmental management framework has been developed as part of the Project to address this issue, and this framework is described in Chapter 16.

3.12 ALTERNATIVE DEVELOPMENT SCENARIOS

Various alternative development scenarios were considered by Wesfarmers/Marubeni in the development of the Project proposal outlined in this ERMP/draft EIS, and detailed in this chapter. The alternative development scenarios centered around two generic options:

- development of the Project Area for the purposes of irrigated agriculture
 - with crops other than sugarcane
 - with a mix of sugarcane and other crops
- development of only a portion of the Project Area for the purposes of irrigated agriculture, with the balance of the Project Area left undeveloped.

Discussion of each of the alternatives follows.

3.12.1 Alternative crops

In preparation of this proposal, Wesfarmers–Marubeni considered in detail a number of broadacre cropping alternatives for the Project Area. Of the alternative broadacre crops,

sugarcane was considered by Wesfarmers–Marubeni to be the most attractive option for the Project Area on the following grounds:

- there are considered to be solid long term market opportunities for raw sugar, both in the Asian region and other world markets;
- there are excellent local conditions for the growing of sugarcane in the ORIA, relative to other regions in Australia and overseas;
- the commercial production of sugarcane in Ord Stage 1 in recent years has had a successful track record, which has validated the results of decades of scientific sugarcane trials performed in the East Kimberley;
- sugarcane grown in the Project Area would have a minimal requirement for on-farm chemicals, particularly in relation to the alternative broadacre cropping alternatives considered.

Various alternatives were considered with respect to development of the Project Area with a mix of broadacre crops. The alternatives were centered around having sugarcane as the ‘base’ crop, and also having land within the Project Area dedicated to the growing of alternative broadacre crops. The conclusion drawn from detailed analyses of these options was that economies of scale are significant with respect to the growing of sugarcane, and the subsequent processing to produce raw sugar. Furthermore, that dedication of any significant portion of the Project Area to an alternative broadacre crop in parallel with development of a sugar industry may marginalise the economics of the sugar industry.

Horticultural cropping options were also considered for the Project Area, but these options were discounted due to the soil types within the Project Area, and the economic imperative that the Project Area is developed rapidly. It is the view of Wesfarmers–Marubeni that horticultural crops would be well-suited to the proposed Ord Stage 2 Riverside Developments (Section 1.1.3 refers).

3.12.2 Partial development of the Project Area

The proposed development is to occur on the Weaber, Keep River and Knox Creek plains. Alternative development scenarios were considered based upon:

- development of the Weaber plain *only*;
- development of the Weaber and Keep River plains but *not* the Knox Creek plain;
- development of the Weaber and Knox Creek plains but *not* the Keep River plain;
- development of the Weaber plain in accordance with the Project programme (Section 3.1.3 refers), but *postponing* development of the Keep River and Knox Creek plains beyond the proposed development schedule.

The conclusions drawn from analyses of the aforementioned development scenarios were as follows:

- Any significant reduction in the scale of the proposed sugar industry for the Project Area would lead to a reduction in the economies of scale. In turn, this would decrease the cost competitiveness of the proposed export industry in relation to other sugar production regions of the world, and potentially jeopardise the long term economic viability of the proposed development.

- Any significant reduction in the Project Area would lead to increased unit costs associated with the provision of infrastructure from Kununurra. A significant portion of the infrastructure investment required to service the Project Area for irrigation and drainage, roads, power and communications would be expended to service the Weaber plain only, and development of the Keep River and Knox Creek plains would involve only incremental investment in infrastructure. Development of the entire Project Area would mean that the total infrastructure cost could be spread more evenly over the Project Area as a whole, thereby reducing the unit investment cost, and unit fixed operating costs. The net result would be a proposed development with a greater chance of long term economic viability.
- Postponement of development of the Keep River and Knox Creek plains to some unspecified point in the future would lead to a transition period within which the disadvantages of a reduced scale of development would prevail. In the transition period, significant uncertainty would prevail with respect to the future of the industry, and sub optimal economics would prevail.
- A decrease in the scale of the proposed development may actually lead to a decreased expansion of the conservation estate in Western Australia and the Northern Territory (Chapter 10 refers).

3.12.3 Conclusion

It is the view of Wesfarmers–Marubeni that the proposed development scenario is the most robust of all the options considered, from an agronomic, economic, community and environmental perspective.

4 Physical environment

This chapter describes aspects of the physical environment, including climate, landforms, and soils in and around the Project Area. The key issues addressed are erosion, sedimentation and potential changes to soil chemistry. Issues relating to surface waters and groundwater are covered in Chapter 5 and Chapter 6 respectively.

4.1 CLIMATE

The climate of the Project Area is typical of the Kimberley region, with two dominant seasons—a wet and a dry season. The wet (monsoon or cyclone) season usually extends from November to April, while the dry season can be taken as May to October. During the wet season, temperatures and rainfall are relatively high with much of the rain activity coming from thunderstorms and cyclones formed in subtropical low-pressure systems off the coast. In contrast, the dry season is characterised by lower temperatures, low rainfall and lower humidity.

The mean daily maximum temperature in Kununurra exceeds 37°C from October to December, after which temperatures decline slightly due to increased cloudiness and humidity (Figure 4.1). Average daily minimum temperatures reach 26°C in December and even in the coldest month, July, do not drop below 15°C.

The average annual rainfall at the Kimberley Research Station from 1946 to the present is 776 mm, with around 90% occurring during the wet season. In the extremely dry year of 1952, only 403 mm was recorded while in the wet year of 1959, 1,448 mm was recorded. Some showers may occur during May, June, July and October (60–100 mm have been recorded at least once in these months); however, August and September consistently have very low rainfall with a maximum recorded monthly total of some 30 mm. The variability of rainfall increases with latitude from north to south, with the lower Ord Valley (which is representative of the Project Area) experiencing relatively predictable rainfall.

Net evaporation rates are generally high, of the order of 2,100 mm/a. During most months, evaporation exceeds precipitation.

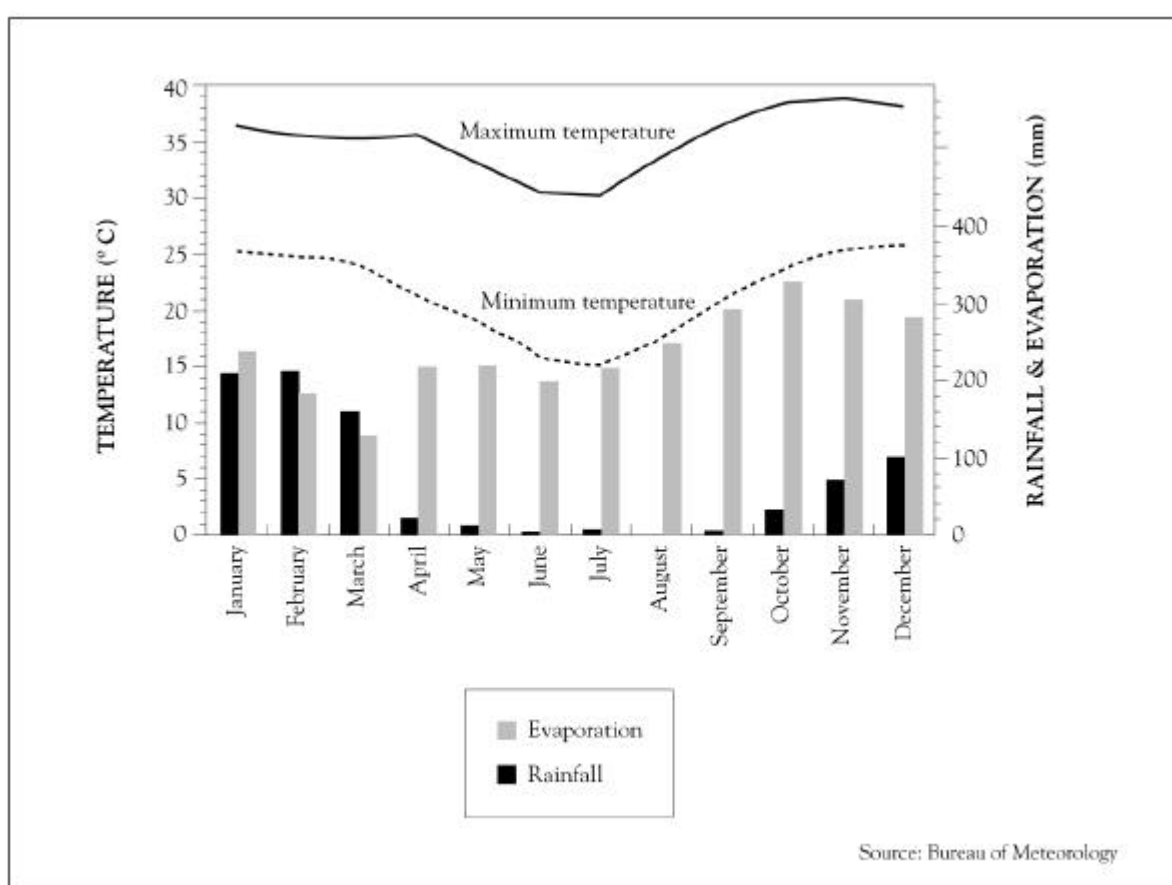


Figure 4.1 Average climatic data for Kununurra

4.2 GEOLOGY

The geology of the Kimberley is relatively complex, and is the principal determining factor for the form of the landscape. Detailed descriptions of the geology of the Ord River area can be found in Traves (1955), Dow and Gemuts (1969), and Mory and Beere (1985; 1988). From these accounts it is evident that the geology of the Project Area and its surrounds is dominated by a basement of sandstones, shales, limestones and conglomerates overlain by 5–25 m of alluvial sediments deposited by the Ord and Keep rivers.

The area that would be developed as part of the Project (Project Area) is confined to three fluvial plains: the Weaber Plain, the Keep River Plain and the Knox Creek Plain. The Weaber and Knox Creek plains form wide and generally flat valleys at an elevation of approximately 25 m Australian Height Datum (AHD). The Keep River Plain, located adjacent to the lower reaches of the Keep River, has an elevation varying from about 20 m AHD in the south-west to about 10 m AHD in the north-west.

The Weaber, Keep River and Knox Creek plains are characterised by little undulation in topography. Rivers and creeks incise the topography only locally and to a maximum depth of about 5 m. The plains contain occasional craggy breakaways of rock, for example, Folly Rock, which rises steeply within the Weaber Plain to approximately 140 m AHD. On the fringes of the river plains there is generally a very marginal rise in the topography due to the presence of aeolian sand deposits, with the most notable deposit occurring along the Pincombe Range.

The hills local to the Project Area are generally steep and rocky. They are largely devoid of vegetation and rise up to about 200 m above the level of the surrounding country. A steep pediment generally marks the transition from hill to plain and is present at the base of most of the hills.

Limestone and sandstone formations are of particular interest as karst systems or caves can develop in these materials. Such systems can potentially provide habitat for subterranean fauna. There are, however, no occurrences of limestone outcrops inside the area proposed for development. The nearest are as follows:

- A dolomite outcrop north-west of Folly Rock, located in conservation area within the Project Area (Chapter 10 refers).
- Inter-bedded sandy limestone outcrops occur at the foot of the Weaber Range; however, the beds are too thin and the sand content too high for cave development (Humphreys 1995). The foot of the Weaber Range approximates the northern extent of the Project Area on the Weaber Plain. The Project Area would contain undeveloped land surrounding that developed for farms, and this undeveloped land would be managed for conservation. The developed land would generally occur some 0.5–1 km south of the foot of the Weaber Range.
- South of the Project Area, the Cave Spring Range and the Pincombe Range consist mostly of inter-bedded sandstone and siltstone. While the former contains a well-known cave at Cave Spring, these ranges are generally not considered suitable for extensive cave formation (Humphreys 1995).
- Limestone formations in the Jeremiah Hills contain some significant cave systems, one at least with a horizontal extent of more than 10 km (Humphreys 1995). The Jeremiah Hills, however, are located well outside the Project Area, being some 4 km to the west.
- A small isolated limestone outcrop about 2 km long by 500 m wide occurs approximately 2 km north of the westernmost farm proposed for the Weaber Plain (shown as W21 in Figure 3.2). The proposed conservation buffer area surrounding the farmland is 1.5 km at this location, which places the limestone outcrop some 0.5 km outside the Project Area. This outcrop has not been surveyed for the presence of caves and associated fauna.

4.3 LANDFORMS

The regional land systems, including those of the Project Area, have been described by Stewart (1970) and are shown in Figure 4.2. The Project Area generally comprises fine-textured fluvial plains of the Ivanhoe Land System that are flat to gently undulating, with localised variation in topography and soil types. The Ivanhoe Land System has traditionally been the primary target for irrigation projects because of its relative uniformity, gentle slopes and suitable soils.

Surrounding the Project Area are the following landforms:

- the Cockatoo Land System, made up of gently undulating plains on sandstone and calcareous sandstone, or deep sands;
- rugged hilly country with ridges, hogbacks, cuestas and structural plateaux of the sandstone, calcareous sandstone and conglomerate rock outcrops of the Weaber Land System, or of the sandstone, siltstone and shale rock outcrops and skeletal soils of the Pinkerton Land System;

- gently sloping alluvium with leached yellowish loamy and sandy soils of the Angallari Land System and undulating plains on dolomite and shale, leached loamy soils with moderate limestone outcrop of the Dinnabung Land System;
- estuarine alluvium cracking clay and solonetzic soils of the Legune Land System;
- estuarine alluvial plains, saline soils and bare mud of the Carpentaria Land System.

4.4 SOILS

The distribution of Great Soil Groups, as defined by Stace et al. 1968, within Land Systems found within or close to the Project Area is given in Table 4.1.

Table 4.1 General soil profiles and Great Soil Groups in Land Systems within or close to the Project Area

General soil profile	Great Soil Group	Occurrence in Land System							
		Pi	W	Cc	D	Ag	Iv	Lg	C
Leached gradational soils	Red earth (sandy)		m	D		m	m		
	Red earth (loamy)	m		m	S	m	m		
	Yellow earth (sandy)		m	S		S			
	Yellow earth (loamy)	m			D	D			
	Lateritic podzolic								
	Meadow podzolic					m			
	Acid swamp								
Cracking clay soils	Grey and brown heavy texture				m		D	S	m
Texture contrast soils	Red-brown earths								
	Solonetzic			m		m			m
Calcareous soils	Rendzina				m				
	Grey and brown calcareous				m				
Undifferentiated	Skeletal	D	D	m	S				
	Alluvial	m					m		
	Solonchak							m	D
	Aeolian								m

Legend: D=dominant, S=subdominant, m=minor.

Pi=Pinkerton, W=Weaber, Cc=Cockatoo, D=Dinabung, Ag=Angallari, Iv=Ivanhoe, Lg=Legune, C=Carpentaria.

Source: Stewart et al 1970

Soil surveys within the Project Area have been undertaken by Aldrick and Moody (1977), Dixon (1996), Schoknecht and Grose (1996) and Schoknecht (1998). These have shown that cracking clay soils, known as Cununurra and Aquitaine clays, are dominant within the Project Area. Smaller areas of red-brown earths, red earths, brownish cracking clays, colluvial outwash slopes, rock outcrops and other soils also occur. The distribution of these soils is shown in Figure 4.3.

Cracking clay soils are common on the Australian continent, with major occurrences in the Northern Territory, western Queensland and New South Wales. However, they are uncommon in Western Australia, with relatively small areas present in isolated areas in the northern parts of the State (Hubble et al. 1983).

Cracking clay soils are often described as black soils or vertisols. They exhibit significant shrinking and swelling properties resulting in deep, open desiccation cracks into which vegetation will often fall. This then becomes incorporated into the soil mass, giving the dark grey or black colouration. Continuous movement due to moisture variations can result in slickensides or polished surfaces within the soil profile. The extreme shrinking and swelling can also result in *gilgai* or melonhole structures, giving the local topography a slight undulation.

Black soils are commonly associated with deep weathering of underlying calcareous or basic rocks. However, there are a number of factors that suggest that the black soils within the Weaber, Keep and Knox Creek plains may be transported soils. These factors include the presence of alluvial materials (clays, clayey sand and sand) immediately underlying the black soils, the apparent absence of basic bedrock geology in the area, and the general absence of any substantial amount of silica, which would be present if the soils were the weathering product of sandstones and siltstones. Crystals of gypsum, believed to have precipitated post-deposition, are also present in the black soils of the Project Area.

A summary of the soil's physical and chemical characteristics from a selection of representative Cununurra and Aquitaine clays within the Project Area is presented in Table 4.2 (guidelines for cropping are shown in Table 4.3). Of interest is the soil pH, which is generally in excess of 7, which indicates that alkaline soils are typical of the Project Area. Acid sulfate soils are not known to occur in the vicinity of the Project Area. The soil types found in the Project Area are described further below.

Table 4.2 Selection of soil's physical and chemical properties within the Project Area

Soil	Depth	Range	Electrical conductivity* (mS/m)	pH*	Nitrogen (% < 2 mm)	PhosphorusH (ppm)	Organic carbon (% < 2 mm)
Weaber Plain							
Aquitaine clay	Surface	min.	7	6.6	0.02	58	0.23
		max.	58	8.0	0.05	150	0.74
	150 cm	min.	16	8.2	0.01	51	0.13
		max.	159	9.2	0.02	91	0.27
Cununurra clay	Surface	min.	8	7.4	0.04	59	0.52
		max.	8	8.2	0.04	74	0.54
	150 cm	min.	72	9.0	0.02	62	0.28
		max.	115	9.4	0.02	160	0.39
Knox Creek Plain							
Cununurra clay	Surface	min.	10	6.7	0.03	53	0.44
		max.	64	7.1	0.05	98	0.90
	150 cm	min.	58	7.8	0.01	40	0.01
		max.	480	8.8	0.01	100	0.09
Keep River Plain							
Cununurra clay	Surface	min.	7	6.6	0.02	—	0.43
		max.	27	8.1	0.07	—	1.01
	150 cm	min.	68	8.0	—	—	—
		max.	1163	9.0	—	—	—

* In mixture of one part soil and five parts water.

H Leached with 6M HCl.

— Indicates data not available

Sources: Dixon 1996; Schoknecht and Grose 1996; Department of Industries and Development 1977.

Table 4.3 Guidelines for cropping

Soil property	Guidelines
Electrical conductivity (mS/m)	If > 200 in surface soil, 10% yield decline (Hunsigi 1993).
pH	Range of 6–7.5 preferred (Baker and Eldershaw 1993).
Nitrogen (% < 2 mm)	Preference for optimal crop growth is > 0.15 (Baker and Eldershaw 1993).
Phosphorus (ppm)	Preference for optimal crop growth is > 36 (Baker and Eldershaw 1993).
Organic carbon (% < 2 mm)	Preference for optimal crop growth is > 1.5 (Baker and Eldershaw 1993).

Cununurra clay

A typical profile of Cununurra clay consists of a 50 mm loose, self-mulching surface layer overlying 1.2–1.4 m of strongly structured, very hard, medium to heavy clay. Below this depth the clay grades into reddish parent alluvium. Shrinkage cracks generally penetrate to approximately 200 mm. A number of distinct phases or variants occur for the Cununurra clays including ‘normal’, ‘leached’, ‘eroded’, ‘brown’, ‘darker’ and ‘flooded’ (Schoknecht and Grose 1996). These vary in both drainage characteristics and soil chemistry.

Electrical conductivities are very high in subsoils below Cununurra clays on the Knox Creek Plain and in places on the Keep River Plain (480–1,163 mS/m). There is a strong possibility of soil salting if the groundwater is allowed to rise and, consequently, it is proposed that control be exercised over water application and that this be combined with groundwater monitoring and management.

Aquitaine clay

Aquitaine clay is also a cracking clay soil, but it is generally found in flatter, lower lying areas than in the Cununurra clay. Aquitaine clay occurs over much of the western and north-western parts of the Weaber Plain and portions of the southern and eastern margin of the Keep River Plain.

Aquitaine clay areas are subject to more frequent, prolonged inundation and generally have a higher clay content than Cununurra clays. They also exhibit a weaker self-mulching behaviour, and have a coarser underlying structure. The subsoil below about 1.3 m is yellowish to brownish with some mottling.

Aquitaine clays can be more susceptible to drainage problems and salinisation than Cununurra clays due to their lower permeability (Riley et al. 1993). However, the major occurrences of Aquitaine clays in the Project Area are on the Weaber Plain, and on this plain the Aquitaine clays appear to have salinity and sodicity characteristics similar to those of Cununurra clays.

Other soils

Other than Cununurra and Aquitaine clay soils, a range of other soils can be found on the Weaber, Keep River and Knox Creek plains. These include red-brown earths (Weaber and Bonaparte), solodic red-brown earths (Bentons) and small rocky outcrops. Small areas of Cockatoo sands also occur on the south-west periphery Knox Creek Plain.

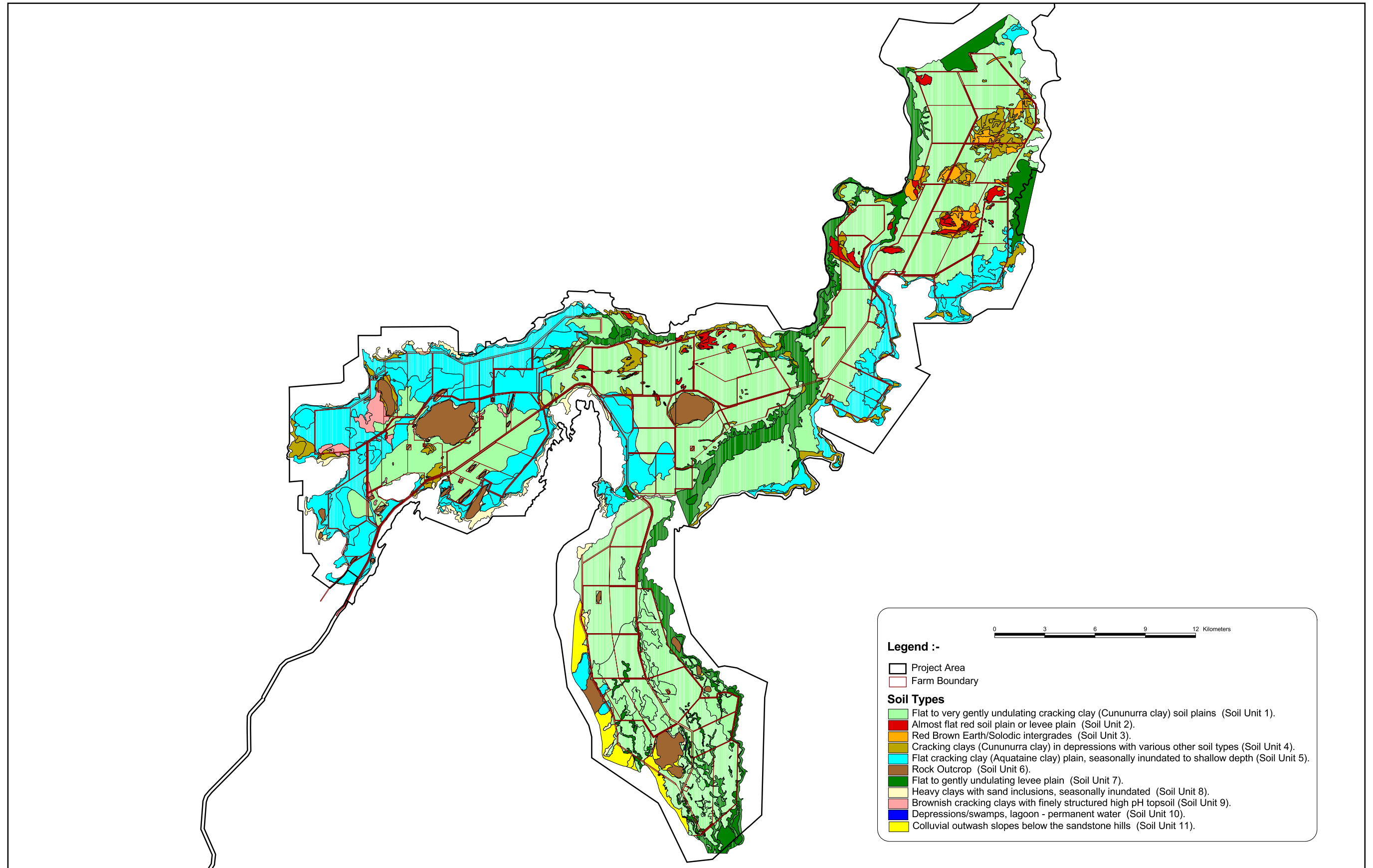


Figure 4.3 Soils of the Project Area

Sand, silt and gravel are present in areas of very limited extent, and are principally confined to incised drainage channels. At a number of creeks, particularly in the Knox Creek Plain, there is a thin cover of alluvium extending beyond the channel, indicating periodic high-energy overbank discharge.

Poorly drained and highly variable soils, generally heavy clays with sand inclusions, occur around the margins of the Weaber Plain, on the eastern boundary of the Ivanhoe Plain and surrounding rocky outcrops in the Knox Creek and Weaber plains. These soils are located outside the proposed farm development area.

4.5 PREDICTED IMPACTS AND THEIR MANAGEMENT

The Project would not affect the climate or geology of the area; however, some impacts on landform and soils may occur. These potential impacts, and the manner in which they would be managed, are described below. Management and monitoring measures proposed are described further in the outline Environmental Management Plan provided as Appendix O.

4.5.1 Landform

The landforms within the Project Area would be modified from the existing primarily natural state to become a highly managed agricultural landscape. The drainage patterns of the plains would be modified to provide a more consistent gradient and to facilitate optimum water application and drainage. In addition, a formal drainage system would be developed within and around the Project Area.

4.5.2 Erosion

Soil erosion in the Project Area would be controlled by a combination of the following management strategies:

- controlling drainage by providing levee banks to prevent floodwaters entering the developed area;
- grading land on farms to gentle slopes to minimise stormwater runoff velocities;
- sizing and designing receiving drains to accommodate anticipated flow regimes;
- providing buffer zones on both sides of watercourses to allow riparian vegetation to continue to stabilise soils in these areas;
- rehabilitating disturbed areas:
 - as soon as possible following disturbance during construction;
 - by formulating and implementing appropriate rehabilitation plans and programmes including topsoil stripping and stockpiling, land preparation, and reseeding with local, native species to facilitate regeneration of disturbed areas;
- managing crops in such a way that crop cover of the soil is maximised, particularly during the wet season when erosive rainfall events may occur.

Monitoring and remediation of erosion would also occur as part of normal operations within the Project Area.

4.5.3 Sedimentation

In their natural state, regional rivers carry high silt loads without showing significant signs of sedimentation in their lower reaches. This factor is due to a combination of the fine-grained nature of the silt load and the high-energy environments within the rivers during wet season flows.

Drainage waters leaving farms would first pass through farm drains and tailwater return systems that would settle and collect larger soil particles, such as coarse silts and sands. The remaining silt load would be similar to that in the regional rivers, and thus sedimentation of downstream watercourses is not expected to occur. Farm maintenance would include regular desilting of these drains and the return of the collected material to the cropped area.

4.5.4 Soil chemical status

The application of water and fertiliser may impact on the natural physical and chemical status of the soil. Such impacts may include:

- increased levels of salt and sodium ions (sodicity) specifically associated with irrigation;
- an increase in soil-available-nutrient status resulting from the application of fertiliser and from natural nitrogen fixation from leguminous crops;
- long-term changes in the overall balance of macro- and micronutrients in the soil reflecting the cropping and fertiliser regimes.

A review carried out in ORIA Stage 1 by Lavelle (1983) concluded that salinity and sodicity were not a problem at that time. However, Lavelle noted a high relative bicarbonate concentration (110 mg/L) in the irrigation water and preferential precipitation of calcium on to the soil and release of sodium. This created a potential hazard to irrigation, particularly for the cracking clays, which have a high susceptibility to sodium damage.

The extent of the sodicity hazard was further investigated by the Department of Agriculture (George 1983, unpublished). Profile cores were taken from eighteen farms with irrigation histories of from two to twenty-three years, but with most being around sixteen years. Cores were also taken from three virgin sites. The results are displayed in Table 4.4. The main findings may be summarised as follows:

- Soil salinities were universally low and safe for plant growth. There was a tendency for soluble salts to increase with depth, the main increase being below about 1 m.
- The exchangeable sodium percentage (ESP) levels of Cununurra clay are low (< 3) at the surface but increase with depth to values of 10–20. Virgin Aquitaine clay has higher ESPs of 4–6 at the surface, increasing to 27 at depths between 1.2 m and 1.5 m. These levels are quickly reduced under irrigation.
- Soil pH levels are high, reflecting the presence of free calcium carbonate in most horizons. Where the pH is greater than 9.1, the ESP is usually greater than 10–12.
- The increase in ESP with depth is caused by the precipitation of the calcium carbonate derived from the irrigation water as its concentration is increased by water uptake by the crop.

Table 4.4 Soil salinity (EC_e) and ESP levels under various blocks in ORIA Stage 1

Block	Soil type	Depth 0–0.3 m		Depth 1.2–1.5 m		Years of cropping
		EC _e (mS/m)	ESP	EC _e (mS/m)	ESP	
36/9	C	56.2	1.4	56.3	11.4	16
36/10	C	43.3	1.5	56.7	10.8	16
36/11	C	51.0	1.4	63.2	12.0	16
36/12	C	43.5	1.6	94.1	14.7	16
63/2	C	65.3	0.4	106	10.4	14
63/4	C	36.7	2.6	272	14.8	18
38	W	57.1	2.5	277	24.3	14
75	A	49.2	3.8	241	14.5	15
113	A	34.3	1.5	104	9.5	2
KRS/1A	C	54.4	1.4	80.4	11.4	18
KRS/4A	C	46.1	2.5	76.4	20.6	23
46	C	24.8	0.7	53.0	12.5	19
54	C	18.8	0.2	35.9	3.7	19
72	C	26.1	0.1	40.1	2.7	15
89	C	64.5	3.3	481	20.7	18
97	C	40.6	2.0	298	20.3	17
106	C	38.7	2.8	279	17.8	7
28	C	–	3.4	–	20.3	18
87	C	19.7	1.2	382	13.9	Virgin
68	A	51.4	7.8	576	27.0	Virgin
68	T	60.6	5.2	1040	18.7	Virgin

Legend: C = Cununurra clay, A = Aquitaine clay, W = Walyara, T = transitional (Cununurra to Aquitaine).

EC_e = electrical conductivity of saturation extract.

Source: George 1983 (unpublished).

George's results confirm work carried out earlier by Aldrick et al. (1978), which found that ESPs at depths of below 0.6 m increased with as little as two irrigations (see Table 4.5). Relative stability in the values resulting from irrigation was also achieved.

ESP levels above 6 cause soil dispersion and a lowering of hydraulic conductivity. Dispersion tests carried out on the samples confirmed that, at below an ESP level of 6, none of the samples were dispersive, while above an ESP level of 16 virtually all of them were dispersive.

Table 4.5 Effect of cropping history on ESPs of Cununurra clay

Depth (cm)	Inundated crops			Furrow-irrigated crops			
	Virgin	Two rice crops	Four rice crops	Virgin	Two crops	Three crops	Seven crops
0–30	1	1		1	2	2	2
30–60	3	4	4	2	6	5	4
60–90	7	10	7	6	12	10	9
90–120	10	16	10	8	17	15	14
120–150	12	19	13	10	19	17	17
150–180	13	20	14	10	19	19	19

Source: Aldrick et al 1978.

Considerable work on sodicity has been carried out in Queensland and a relationship between ponded infiltration rates and ESP at 0.9 m depth has been established for soils in the Emerald area (Shaw and Yule 1978). This relationship, shown in Figure 4.4, confirms the relationship between increasing dispersion (and hence lower hydraulic conductivity and infiltration) with higher ESP. Shaw (1988) also reports that an ESP of 15 can be tolerated at subsoil depths, particularly if the soil is a cracking clay. Based on the Queensland experience, a target ESP of 15 at 1.3–1.5 m depth has been adopted for the Project.

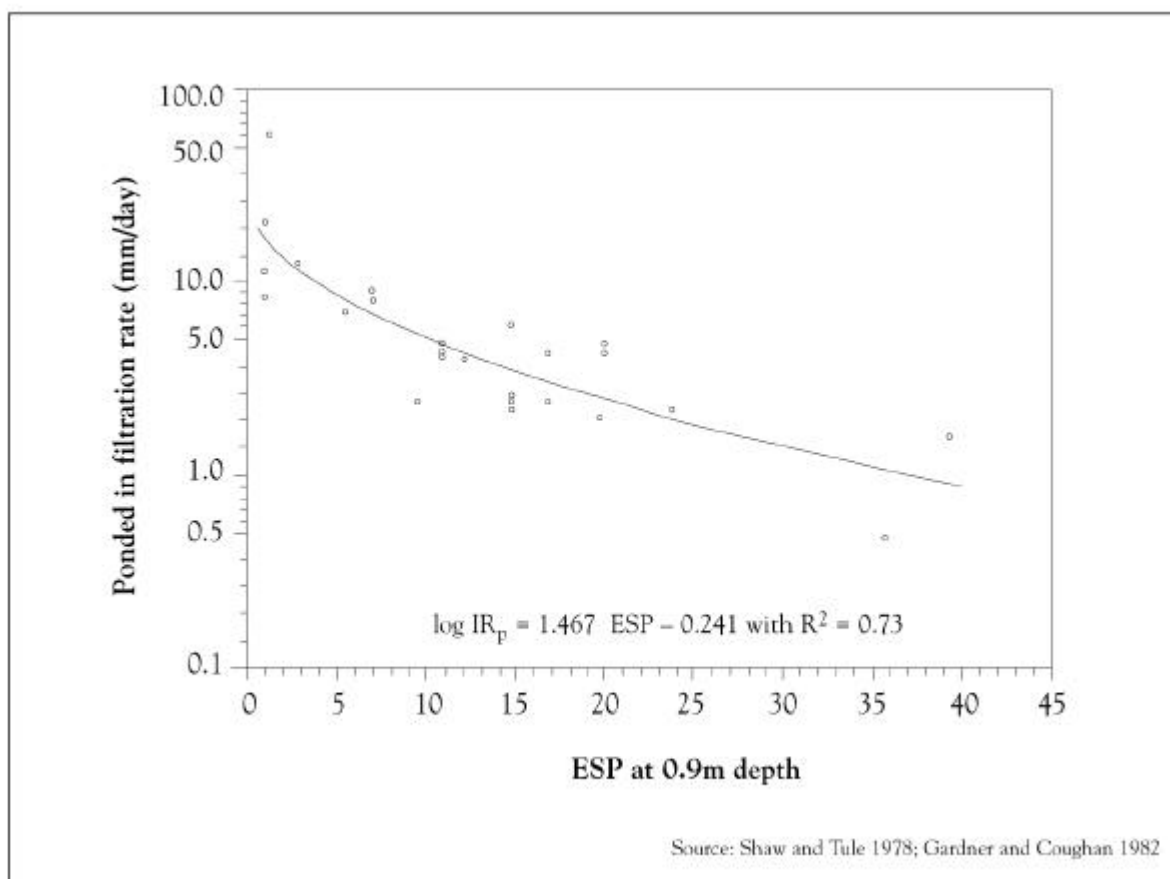


Figure 4.4 Relationship between Pondered Infiltration Rate and ESP

The ESP profiles shown in Table 4.4 also include those for two blocks of the sugar pilot farm in ORIA Stage 1, where various irrigation techniques were trialled as follows:

- Block 63/2 was flood irrigated and had a leaching factor in the range of 0.07–0.11. (The leaching factor is the proportion of applied water, including rainfall, that passes the root zone of the crop.) The ESPs on Block 63/2 were all reduced below that of the virgin soil, and the ESP at 1.2–1.5 m was 10.4 and therefore below the limit of 15 adopted for the Project.
- Block 63/4 was furrow irrigated and had a leaching factor in the range of 0.03–0.04. The ESPs on Block 63/4 were all slightly above the virgin state and the ESP at 1.2–1.5 m was 14.8, at approximately the acceptable limit adopted for the Project.

Sodicity issues would be managed indirectly through management of irrigation practices. Numerical modelling of accessions to groundwater, described in Appendix H, has shown that the irrigation practices proposed for the Project would result in leaching rates past the crop root within the range 56–119 mm/a, with 94 mm/a being the predicted rate for average

soil and meteorological conditions. A leaching rate of 94 mm/a corresponds to a leaching factor of about 0.04. Based on the above data it would appear that this leaching factor of 0.04 would be acceptable as it would maintain subsoil ESPs around the virgin levels and below 15.

Long-term monitoring would be undertaken to ascertain any changes to surface and subsoil salinity and sodicity resulting from the proposed irrigation practices, for example by assessing sodium adsorption ratio, ESP and electrical conductivity levels. Alternative management measures would be investigated and trialled if the monitoring should detect an increase in subsoil sodicity levels sufficient to threaten the long-term sustainability of the Project. These management measures could include:

- the application of gypsum to either the cropped area or the irrigation water;
- the blending of groundwater with irrigation water to increase the salinity of the water applied to the cropped area;
- a change in irrigation practices, to result in a greater leaching factor than that proposed at the present time.

The first two of the above management methods would result in a beneficial change in irrigation water chemistry with respect to the control of sodicity. The third method would result in a greater rate of seepage to groundwater, and a potential requirement to bring forward and increase the groundwater management measures proposed for the Project as described in Chapter 6. The converse scenario is also a possibility in that monitoring may indicate that a lower leaching fraction to that currently proposed may be acceptable to control salinity and sodicity. In this case, the irrigation practices would be modified to reduce the accessions to groundwater, thereby conserving water and reducing or postponing the Project's groundwater management requirements.

Within the irrigation area, the chemical status of the soil would also be routinely assessed as a component of ongoing management. This would include regular assessment of soil chemistry, including macro- and micronutrient status, organic matter content and pH. Records of soil tests would be maintained to develop a history of soil chemical and physical status.

5 Surface water

This chapter outlines the issues associated with management of surface waters for the Project, including the relationship with other developments through the Draft Interim Water Allocation Plan for the Ord River. In particular, the management of water on farms is examined, including the effects water runoff from the croplands would have on receiving waters downstream of the Project Area. The chapter also outlines anticipated changes in local hydrology that may result from the proposed development.

5.1 OVERVIEW

As with ORIA Stage 1, releases of water from Lake Argyle, flowing via Lake Kununurra would be the source of irrigation water for the Project. The distribution of water from Lake Kununurra to the Project Area would be via the purpose-built M2 Channel.

The Keep River, located between the Ord and Victoria river catchments, is the most significant watercourse draining the Project Area. In addition to the Keep River, Sandy Creek drains the easternmost fringes of the Keep River Plain. The entire Project Area would be contained within the lower reaches of the Keep River and Sandy Creek catchments. Both the Keep River and Sandy Creek discharge into Joseph Bonaparte Gulf.

Nearly all rivers and streams in the region flow only in the wet season. Permanent water is therefore restricted to sheltered pools and billabongs that retain water during the dry season, and the tidal reaches near the river mouths. Pools and springs are important refuge areas for fauna in an otherwise seasonally dry environment.

Wet-season flows in all rivers and streams typically have high turbidity levels reflecting high sediment loads. The exception is the Ord River downstream of the Ord River Dam. This dam acts as a sediment trap, and hence water released downstream of the lake is low in suspended solids.

5.2 ORD RIVER

The Ord River rises near Halls Creek and has a catchment area of some 64,000 km². It is approximately 650 km long and flows via Lake Argyle and the Kununurra Diversion Dam on route to the Cambridge Gulf. The Dunham River, a major tributary of the Ord River, enters the latter approximately 2 km downstream of the Kununurra Diversion Dam. The Dunham River is unregulated.

Prior to construction of the Ord River Dam in 1971, the lower Ord River normally ceased flowing for at least two or three months at the end of each dry season between June and October. River regulation since dam construction has resulted in perennial flow downstream of Lake Argyle.

The farm area associated with the Project would be contained entirely within the catchments of the Keep River and Sandy Creek, and hence drainage waters from the Project Area would not be discharged into the Ord River. Consequently the only impact of the Project on the Ord River would be through the diversion of water for the irrigation scheme. This diversion of water is included in the Draft Interim Water Allocation Plan (Water and Rivers Commission 1999) for the Ord River (Sections 5.2.1, 5.2.2 and 5.2.3 refer). The scope of this ERMP/draft EIS does not include consideration of this diversion of water from the Ord River.

5.2.1 The Draft Interim Water Allocation Plan for the Ord River

The Water and Rivers Commission is the authority in Western Australia responsible for managing the allocation of water resources. The Water and Rivers Commission ensures that water is used efficiently within sustainable limits, and that the needs of people and the environment are balanced.

An important aspect of the allocation process is the preparation and implementation of allocation plans for each water management system, for example a river catchment. These plans define the upper limit of water to be made available for consumption use based on ecological sustainability (ie. after water is allocated for environmental flows), and allocate that water equitably between the different forms of use. That is, they define the amount of water that is allowed to be diverted from river systems and groundwater aquifers, while ensuring sufficient water is maintained to meet the needs of key water-dependent ecosystems. Allocation plans prepared by the Water and Rivers Commission are implemented through licensing under the *Rights in Water and Irrigation Act 1914*.

Licences formalise the allocations and are subject to conditions deemed necessary for good management of the resource. As Western Australia's water allocation system evolves to meet the requirements of the Council for Australian Governments (COAG) Water Reform Framework Agreement, the licences will become the means of identifying water allocations and their holders.

The Ord River has been used for irrigation for more than thirty years, but this use has only involved a small proportion of the available water resource during that time. A hydroelectric power station has been in operation since early 1996, and planning for a major expansion of the irrigation area, including the Project and other components of ORIA Stage 2, is now under way. In order to assist the planning of these projects, the Water and Rivers Commission has prepared a Draft Interim Water Allocation Plan (Water and Rivers Commission 1999) for the Ord River. The Draft Interim Water Allocation Plan was forwarded for review by the EPA in May 1999.

5.2.2 Assumptions made relating to the Draft Interim Water Allocation Plan

The following assumptions have been made by Wesfarmers–Marubeni and the Water Corporation regarding the Draft Interim Water Allocation Plan:

- The water allocation planning process being adopted by the Water and Rivers Commission will provide adequate assessment over time of the effects of the Project on the ecology and other values of the lower Ord River. For this reason, this issue is not addressed directly in this ERMP/draft EIS.

- The final (long-term) water allocation to the Project will be consistent with the interim allocations currently proposed by the Water and Rivers Commission.

5.2.3 Water allocation and licence provision

The Draft Interim Water Allocation Plan tables an interim water allocation of 1,235GL/year as being acceptable for all existing and proposed irrigation uses in the Ord River Irrigation Area. The proposed water allocation for the Project Area is 740GL/year. In assessing the irrigation allocation, the Water and Rivers Commission has had to ensure that there would be sufficient water for all other uses, including water for hydroelectric power generation and Environmental Water Provisions (EWP). A summary for the proposed allocation of water from the Ord River Dam is in Table 5.1.

Table 5.1 The use of water released or flowing from Lake Argyle - for full irrigation development and the generation of 100GWhr of hydro-power per year.

Water released or flowing from Lake Argyle	Average yearly amount (GL/a)
Divertible Allocations for Irrigation Purposes:	
• ORIA Stage 1*	300
• ORIA M2 Development Area (the Project)	740
• ORIA - Other Stage 2 developments	195
Water that contributes to meeting the Interim EWPs [⊙]	510
Hydro-electric power generation only**	150
Overflow ^{⊙⊙}	930
Total	2825

* May be increased to 355 GL/a under certain conditions

⊙ Water that flows over the spillway, through the scour values or through the Hydro-electric stations and the contributes to meeting the interim EWPs downstream

** Releases specifically for hydro power generation - occurs only when hydro-power demand is greater than that needed to meet any other demand.

⊙⊙ Overflow only - water that flows over the spillway and is in excess of the downstream needs of irrigation or the interim EWPs.

Source: Water and Rivers Commission 1999.

In preparing the Draft Interim Water Allocation Plan, the Water and Rivers Commission has made an assessment of the appropriate EWP, prior to making an assessment of the suitable water allocations for irrigation and other purposes. The Draft Interim Water Allocation Plan states that “Until more details study can be carried out, the Water and Rivers Commission considers that the monthly flow volumes in the Ord River just below the Dunham River confluence should be maintained at levels that at least equal the 20th percentile value, which is the monthly flow volume that is not likely to be exceeded on 20% of occasions. The plan also states that the interim Environmental Water Provision (EWP) was largely “to ensure recognition of the need for some level of provisions of water to the environment and to provide a starting point for a more clearly justified EWP”. In preparing the Draft Interim Water Allocation Plan, the Water and Rivers Commission has acknowledged the need for more detailed study of EWP’s, and has adopted a precautionary approach in relation to the proposed consumptive use allocations.

The Water and Rivers Commission is planning for the Interim Plan to be formalised by 2003.

The Draft Interim Water Allocation Plan states that an allocation of 1,235 GL/a is adequate for irrigation purposes, whilst also maintaining flexibility for future allocation decisions. The allocation for irrigation represents approximately 44% of long term average releases from Lake Argyle, at full development of ORIA Stage 2, under the draft Interim Water Allocation Plan.

For the existing irrigation area (ORIA Stage 1), a licensed allocation of an annual average of 300 GL would be issued subject to certain conditions relating to the operation of the distribution system. The Water and Rivers Commission states that it is prepared to allocate up to a further 55 GL for ORIA Stage 1 if clear evidence for the irrigation demand can be demonstrated. This would require evidence that over 90% of the area irrigated is to be planted to sugarcane, and clear field evidence that research estimates of high sugarcane crop water demands were critical for economic production. Improvements in on-farm and distribution efficiencies, and commitments to a sustainable land and water management plan, must also be demonstrated before additional water would be allocated.

In the past, allocation licences have been issued for a maximum of ten years in accordance with established policy, and with an expectation of renewal subject to water being available and licence conditions having been complied with. However, the policy on licence duration and the expectation of renewal are under review as part of the implementation of the COAG Water Reform Framework Agreement. Proposals for longer duration licences, and the Water and Rivers Commission's powers to amend licence conditions during their life, have been considered in this overall reform context over the last twelve months.

It is the intention of Wesfarmers-Marubeni and the Water Corporation to secure a water licence with a duration commensurate with the economic life of the Project.

5.3 KEEP RIVER, SANDY CREEK AND THEIR TRIBUTARIES

5.3.1 Hydrology

Overview

The Keep River rises south-east of Kununurra and has a catchment of some 5,000 km², equivalent to approximately 8% of the Ord River catchment. The headwaters of the Keep River begin just south of the Victoria Highway (see Figure 5.1). After passing through the gorges and low hills of the Keep River National Park, the river emerges on to the cracking-clay plains and flows north and then north-east to drain into the Joseph Bonaparte Gulf.

Major tributaries of the Keep River include Knox Creek, Border Creek and Oakes Creek, which have the majority of their catchments within Western Australia. The areas of these catchments are presented in Table 5.2.

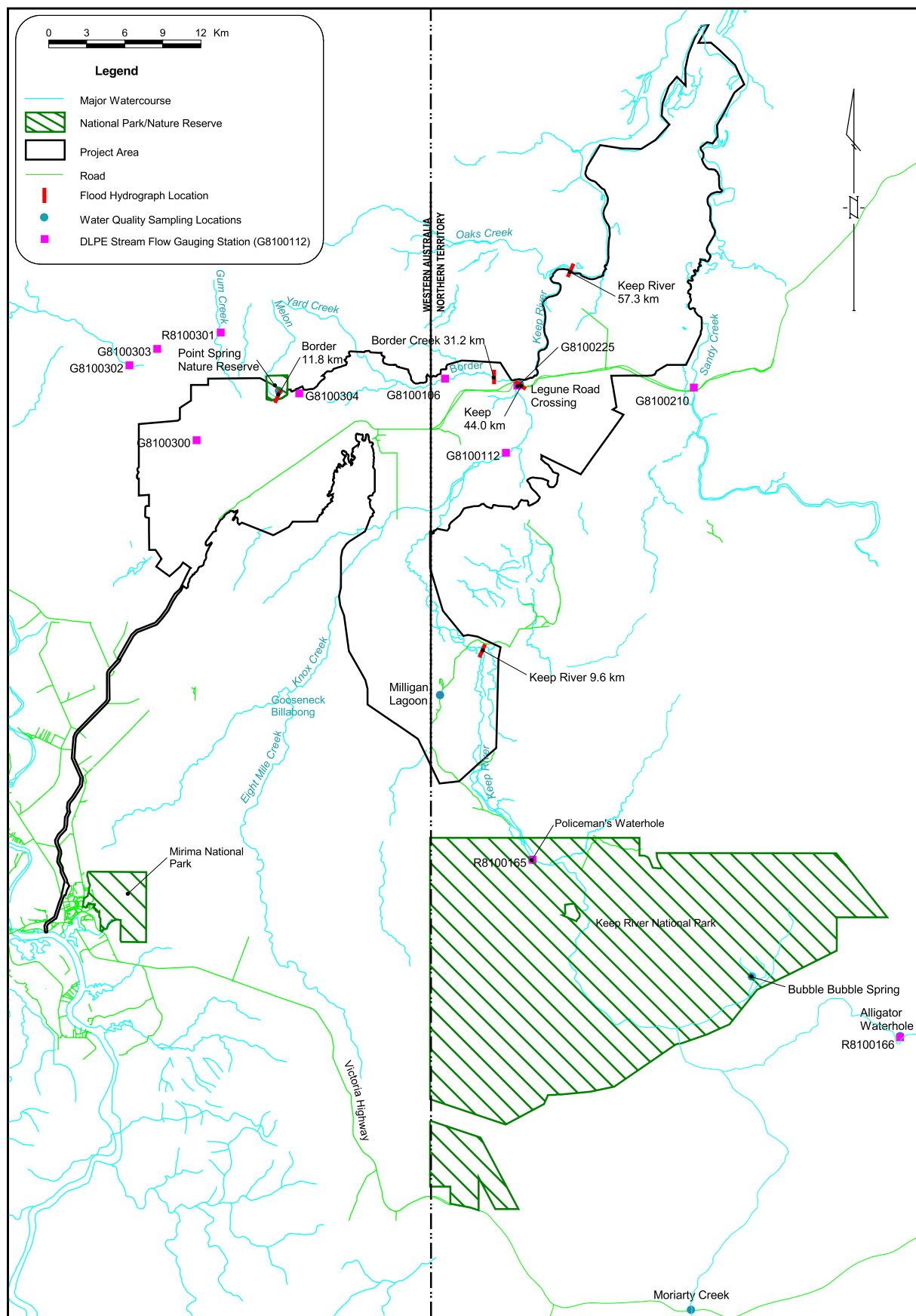


Figure 5.1 Regional Hydrology

Table 5.2 Keep River catchment areas

Catchment	Area (km ²)
Keep River	3,190
Border Creek	1,032
Oakes Creek	243
Knox Creek	577
Total	5,042

Sandy Creek flows into the Keep River estuary. The catchment of Sandy Creek, which has an area of 1,240 km², lies entirely within the Northern Territory.

Hydrological data are collected by the DLPE at several gauging stations on the Keep River and its tributaries and on Sandy Creek. Table 5.3 summarises the stream flow data available for the DLPE gauging stations shown in Figure 5.1.

Table 5.3 DLPE stream flow recording

Site Number	Name	Length of record	Start – End
G8100106	Border Creek	15 years	1971–1986
G8100112	Keep River (N.B. Gridline)	7.5 years	1971–1977
R8100165	Keep River	16 years	1970–1986
R8100166	Keep River	2 years	1972–1974
G8100210	Sandy Creek	2 years	1977–ongoing
G8100225	Keep River	21 years	1964–1986
G8100300	Weaber Plains West	3.5 years	1971–1974
G8100301	Gum Creek	3.5 years	1971–1974
G8100302	Sandy Creek*	2 years	1971–1973
G8100303	Cockatoo Creek	2 years	1971–1973
G8100304	Weaber Plains North	3.5 years	1971–1974

* Tributary of Border Creek in Western Australia

Keep River—upper reaches

While the main watercourse of the Keep River upstream of the Legune Road crossing is reasonably well defined, secondary flood channels parallel to the river exist along most of the river length. This is particularly noticeable at the junction of Knox Creek with the Keep River where there is a series of braided channels approximately 2–3 km wide.

A number of billabongs and lagoons occur on the floodplain of the Keep River, particularly within former drainage lines or anabranches of the river. The largest natural waterbody of this type in or near the Project Area is Milligan Lagoon (Figure 5.1).

Flow data collected by the DLPE at the Legune Road crossing, summarised in Table 5.4, indicates there is virtually no flow in the upper reaches of the Keep River from June through October. The data also indicates a high variation in annual flows.

Table 5.4 Recorded monthly flows in Keep River at Legune Road Crossing

	Mean (GL)	10 th Percentile (GL)	median (GL)	90 th Percentile (GL)
Jan	56.1	4.7	21.7	170.0
Feb	104.8	5.2	57.4	310.7
Mar	131.3	10.4	68.2	313.6
Apr	4.6	0.0	0.8	10.1
may	0.5	0.0	0.0	0.8
Jun	0.0	0.0	0.0	0.0
Jul	0.0	0.0	0.0	0.0
Aug	0.0	0.0	0.0	0.0
Sep	0.0	0.0	0.0	0.0
Oct	0.0	0.0	0.0	0.0
Nov	8.4	0.0	0.0	5.6
Dec	5.7	0.0	2.4	13.4

Source: DLPE data for Site Number G8100225 for period 1971–1986 as interpreted by Sinclair Knight Merz.

Border Creek and the Weaber Plain

The Weaber Plain is relatively flat and large parts are subject to inundation during the wet season. A number of intermittent watercourses from the surrounding hills, including Cockatoo Creek, Gum Creek and Melon Creek, discharge on to the plain. This water spreads out into indistinct sheet flow as the greater part of the plain has no incised channel. Only at the northern extremity of the plain is there defined drainage, and here Border Creek carries water eastwards into the Keep River. However, relatively little runoff reaches Border Creek except in very wet periods. The Pincombe and Cave Spring ranges to the south of the Weaber Plain produce runoff that is generally lost by infiltration or evaporation on the Weaber Plain, with little runoff reaching the downstream gauging point on Border Creek.

Data collected by the Department of Lands, Planning and Environment indicate that no flows have been recorded in Border Creek between June and September. The data also indicate that the Border Creek catchment contributes approximately 12% of the Keep River flows, although representing approximately 20% of the catchment area. Data from stations located further upstream in the Border Creek catchment indicate only sporadic flows after heavy rains late in the wet season.

Point Spring and Cave Spring are two small but permanent waterbodies that occur at the foot of the Weaber Range and the Cave Spring Range respectively. Both are surface expressions of groundwater, fed by infiltration higher up in the respective ranges.

A shallow surface waterbody has formed on the western portion of the Weaber Plain as a consequence of drainage releases from ORIA Stage 1. This waterbody varies in size with climatic conditions and volume of discharge; however, at times it is about 5 km long and 2 km wide.

Knox Creek and the Knox Creek Plain

Knox Creek enters the Keep River some 13 km upstream of the Legune Road crossing. The major tributary of Knox Creek is Eight Mile Creek, which rises just south of the Victoria Highway in the vicinity of Matheson Ridge. An unnamed major tributary of Knox Creek drains Mt Cecil and Abney Hill immediately north of Mirima National Park. The main

drainage line of Knox Creek runs within a kilometre south-west of the Pincombe Range before turning east to the Keep River confluence in the vicinity of the border between Western Australia and the Northern Territory. There are no known flow records for Knox Creek.

The Knox Creek Plain is mostly well drained due to its uniform but gentle slope.

Keep River—lower reaches

Downstream from the Legune Road crossing, the Keep River becomes a series of permanent waterholes separated by rockbars. At the confluence with Border Creek the river opens into a tidal waterbody some 50–100 m wide, which is connected to the Keep River mouth. Oakes Creek discharges into the Keep River in this reach, which becomes progressively wider and tidal to the river mouth. The tidal range at the mouth is approximately 8 m.

Sandy Creek

Sandy Creek is immediately east of the Keep River Plain. At this location its bed is relatively wide and sandy containing sand beds 100 m and 200 m in width both downstream and upstream of Legune Road. Small semi-permanent lagoons or billabongs and sandy strips occur close to the creek. These are primarily associated with old meanders and are most apparent in the vicinity of Legune Road.

Sandy Creek becomes tidal approximately 10 km downstream of the Legune Road.

5.3.2 Water quality

Water quality data in the vicinity of the Project Area have primarily been collected by the DLPE. Sampling has also been conducted by the Power and Water Authority, the Water Directorate (Field 1988), the Water Corporation (December 1995 to July 1996 and February 1998), CSR (April 1996 to November 1996) and the OIC (April 1996 to February 1997), and during the aquatic fauna survey for the Project (Larson 1999). The water quality data available from the surveys are presented in Appendix G.

The range of water quality data collected in and near the Project Area during the wet and dry seasons is presented in Table 5.5 for the Keep River and associated waterholes and in Table 5.6 for other watercourses, including the M1 Channel. The majority of the Keep River samples have been taken from lagoons or pools either at the start or the end of the wet season, when the river was not flowing.

During the wet season the salinity levels in the non-tidal sections of the Keep River are similar to those in the Ord River, with conductivities generally less than 200 $\mu\text{S}/\text{cm}$. During the dry season higher salinity levels (up to 740 $\mu\text{S}/\text{cm}$) have been recorded in pools upstream of Legune Road crossing, indicating the effect of evaporation on this water-quality parameter.

Salinity levels in the Keep River become progressively higher closer to the river mouth as the tidal influences become more substantial.

Concentrations of nutrients sampled in the Keep River and its tributaries during the wet season have ranged from 0.01 mg/L to 0.54 mg/L total phosphorus and 0.12–0.48 mg/L total nitrogen. Land uses in the Keep River catchment involve conservation in the Keep River National Park and pastoral activities. Some of the naturally occurring total

phosphorus levels are above the national guidelines (ANZECC 1992) of 0.01–0.1 mg/L for the protection of freshwater ecosystems.

Only one sample has been collected from the Keep River during the dry season and analysed for nutrients. The level of total phosphorus (0.018 mg/L) in this sample is comparable to the lower values measured during the wet season.

5.4 PREDICTED CHANGES TO THE HYDROLOGY OF THE KEEP RIVER

The hydrology of the Keep River and its tributaries adjacent and downstream of the Project Area would be affected by several features of the Project, including:

- alteration of flow levels and velocities, through containment of flood waters within flood protection levees;
- alteration of surface runoff volumes and timings, through land and drainage modification;
- alteration of dry season flow patterns, due to intermittent, but minimal, releases of irrigation water during periods of equipment failure or during maintenance;
- possible alteration of seasonal flows resulting from groundwater management strategies (section 5.4.4 refers).

5.4.1 Influence of the flood protection levees

Flood protection levees would be constructed around most of the perimeter of the farm development area to prevent flooding of the cropped areas and associated infrastructure in all but extreme conditions. These flood protection levees, described in Chapter 3, would influence the flow levels and velocity within the Keep River, Border Creek and to a lesser extent in Sandy Creek as a consequence of containing floodwaters to a reduced area of floodplain.

The extent of the changes to the hydrology of the Keep River and Border Creek during flood conditions is shown in Figure 5.2. This figure shows typical hydrographs on these two watercourses for both the existing and the post-development scenarios for the following flood conditions:

- frequently occurring flood events, denoted by the 1-year Average Recurrence Interval (ARI) flood hydrograph. By definition, the 1-year ARI flood would occur, on average, once every year;
- infrequent flood events, denoted by the 25-year ARI flood hydrograph. The 25-year ARI flood would be the design flood for the levees; hence it would be contained by the levees;
- extreme flood events, denoted by the 100-year ARI flood hydrograph. The 100-year ARI flood need not be contained by the levees; hence some flooding of the cropped area would be expected.

Of interest are the effects that the levees would have on peak flow levels and velocities as summarised in Table 5.7. This information was derived from the hydrology models used to define the existing and post-development hydrographs (Figure 5.2). The hydrology models were also used to optimise the proposed location of the flood protection levees with respect to minimisation of increases in peak flood levels and velocity.

Table 5.5 Range of water quality data for the Keep River and associated waterholes

Parameter	Keep River		Policeman's Waterhole		Milligans Lagoon		Alligator Waterhole		Bubble Bubble Spring	
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Conductivity (µS/cm)	45–313	182–740	173–209	127–134	73	45–82	77	49–112	316	210–298
pH	7.2–8.4	7.2–8.6	8.1–8.3	7.8–7.9	6.8	6.7–7.2	5.8	4.7–6.8	7.9	7.6–8.2
Turbidity (NTU)	22	1–39	11–12	8–13	11	1–10	10	3–10	2	0–10
Dissolved oxygen (% saturation)	–	85–150	–	–	–	–	–	–	–	–
Dissolved oxygen (mg/L)	6.55	6.60–9.05	6.63–6.65	7.91–8.00	4.30	2.90–7.72	6.03	–	5.25	4.58–8.45
Total nitrogen (mg/L)	0.281	0.355	0.245	0.339	0.712	0.444	0.481	0.352	0.123	0.084
Total Kjeldahl nitrogen (mg/L)	0.280–2.250	0.350	0.240	0.280	0.710	0.440	0.480	0.350	0.120	0.080
Nitrate and nitrite (mg/L)	0.001–19.000	0.005–1.000	0.005–0.426	0.059	0.002–0.492	0.004	0.001	0.002	0.003	0.004
Total phosphorus (mg/L)	0.008–0.540	0.018	0.013	0.013	0.024	0.028	0.031	0.030	0.009	0.013
Free reactive phosphorus (mg/L)	0.003–0.057	0.002–0.056	0.006–0.040	0.002	0.004–0.044	0.007	0.010	0.009	0.007	0.004

– Signifies no data available.

Sources: Department of Lands, Planning and Environment monitoring July 1995 to October 1996, and December 1997 to March 1998; Ribbons of Blue January 1995 and February 1997; Water Corporation December 1995 to July 1996, and February 1998; OIC April 1996 to February 1997; CSR April 1996 to November 1996; Field 1988; and Larson 1999.

Table 5.6 Range of water quality data for other watercourses

Parameter	Knox Creek	Border Creek	Sandy Creek		M1 Channel		Oakes Creek	Moriarty Creek
	Wet season	Wet season	Wet season	Dry season	Wet season	Dry season	Dry season	Dry season
Salinity (ppt)	–	–	41–61	0	–	–	47–49	–
Conductivity (µS/cm)	–	21–94	34–180	< 5–420	–	–	–	440–560
pH	–	–	5.7	7.2–9.1	–	–	–	7.5–8.3
Turbidity (NTU)	–	–	11	1–8	–	–	–	1
Dissolved oxygen (% saturation)	–	–	–	82–110	–	–	–	73–88
Dissolved oxygen (mg/L)	–	–	–	–	–	–	–	–
Total nitrogen (mg/L)	–	–	–	–	–	–	–	–
Total Kjeldal nitrogen (mg/L)	–	0.51–3.88	–	–	–	–	–	–
Nitrate and nitrite (mg/L)	0.500	< 0.2–15.7	< 0.2–7.1	< 1–1.0	0.155–0.505	0.150–0.396	–	< 1
Total phosphorus (mg/L)	–	0.047–0.226	0.010–0.050	–	–	–	–	–
Free reactive phosphorus (mg/L)	0.039	0.150	–	0.011–0.025	0.004–0.027	0.003–0.060	–	0.023–0.045

– Signifies no data available.

Sources: Department of Lands, Planning and Environment monitoring July 1995 to October 1996, and December 1997 to March 1998; Ribbons of Blue January 1995 and February 1997; Water Corporation December 1995 to July 1996, and February 1998; OIC April 1996 to February 1997; CSR April 1996 to November 1996; Field 1988; and Larson 1999.

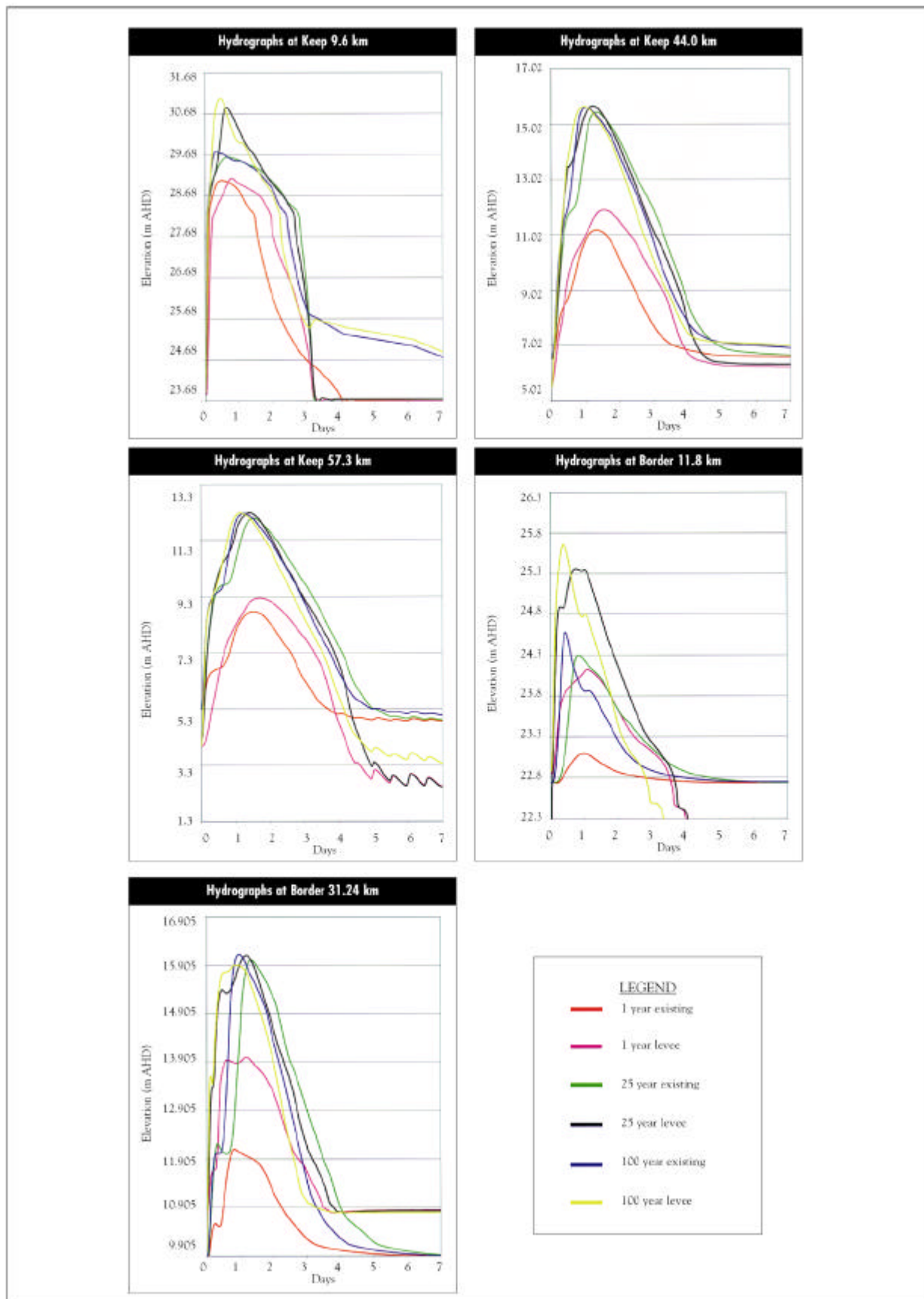


Figure 5.2 Predicted flood hydrographs

Table 5.7 Summary of the influence of flood protection levees on Keep River and Border Creek peak flood height and peak average velocity

Location*	Predicted changes following development					
	Increase in peak flood height (m)			Increase in peak average velocity (m/s) **		
	1-year ARI	25-year ARI	100-year ARI	1-year ARI	25-year ARI	100-year ARI
Keep River 9.6 km (upper development)	Nil	1.2	1.3	Nil	0.2	-0.2
Keep River 44 km (mid-development)	0.7	0.2	Nil	Nil	Nil	Nil
Keep River 57.3 km (lower development)	0.5	0.2	Nil	0.2	Nil	Nil
Border Creek 11.8 km (mid-development)	1.0	1.1	1.1	0.3	0.4	-1.0
Border Creek 31.2 km (lower development)	1.9	0.1	-0.2	1.6	0.8	0.2

* Refer to Figure 5.1 for locations.

** Average velocity is flow rate divided by area of flow.

A criterion adopted for the optimisation process was to restrict peak flood levels from the 1-year ARI development scenario to those defined by the 25-year ARI existing scenario. In other words, peak flood levels from frequently occurring floods were restricted to a less frequently occurring level. In particular, this criterion resulted in flood protection levee FPL1 (shown in Figure 3.4) being moved approximately 200 m south at Border Creek 11.8 km (near farm block W321 and Point Spring). FPL1 would contain Border Creek along the northern edge of the Weaber Plain.

The revised location of FPL1 is also satisfactory because it avoids frequent inundation of Point Spring, located at the foot of the Weaber Range. The natural levee between the wetland associated with Point Spring and the Weaber Plain has a measured elevation of 24.3 m AHD, the same as the predicted peak flood elevation for the 1-in-25-year ARI flood for the development scenario.

In regard to water velocity, the hydrology models predict minor or no increases in peak average velocity at most locations and even a reduction for some of the 100-year ARI scenarios following development. The exception is the location Border Creek 31.2 km on the lower reaches of Border Creek, with significant increases of peak average velocity of up to 1.6 m/s predicted for the modelled scenarios at this location. However, erosion problems are not anticipated due to the rocky nature of the Border Creek substrate at this location.

At the other locations the minor increases in peak velocities would result in predicted velocities in the range of 0.2–0.8 m/s. These velocities are generally less than the value of 1.5 m/s recommended by ID&A (1996) and Chang (1988) as the maximum permissible velocities for streams with substrates of colloidal stiff clays and alluvial silts and fine gravels, which are characteristic of the Keep River and Border Creek. This factor, together with the riparian vegetation that would be maintained along the natural watercourses, would mitigate any erosion effects.

Localised areas of high water velocity may occur at structures constructed across natural watercourses, such as the siphon and bridge crossings of Knox Creek and the Keep River. Appropriate erosion protection measures such as stone pitching and bridge abutments would be developed for these areas as part of the detail design for the Project.

Monitoring of erosion along all watercourses, including constructed drains, would be undertaken as part of the EMP for the Project. Localised management of any erosion would be undertaken on an as-needed basis by the Environmental Management Entity that would be established as part of the Project (see Chapter 16).

5.4.2 Influence of improved drainage of the farm development area

The black-soil plains of the Project Area currently have relatively poor drainage characteristics due to a combination of their low slopes and localised depressions, or gilgai, that hold surface water. In addition, the black soil develops extensive surface cracks over the dry season, and these cracks retain rainwater until the soil expands sufficiently to close the cracks.

Development for irrigated farming would change the rainfall runoff characteristics from these areas in terms of quantity and timing of flows, as a result of the following features:

- the laser planing of the farm units to remove gilgai (localised depressions) features that would provide uniform slopes to facilitate flood irrigation;
- irrigation water application that would prevent soils from drying and forming surface cracks;
- the growing of sugarcane, a perennial crop with high water requirements, over most of the Project Area;
- on-farm water management systems that would trap and hold, for subsequent use as irrigation water, the first-flush runoff from the farm units. The number of times that the first-flush systems would operate during the wet season would vary with the size and timing of storms;
- the construction of drainage infrastructure that would efficiently remove rainfall runoff from the farm units and convey it to streams and rivers.

Quantification of the rainfall runoff from farms planted to sugarcane was undertaken using the LEACHM model. This model, described further in Chapter 6, was utilised to predict the various proportions of irrigation water and rainfall that result in runoff, infiltration or use by the crop. For average years, the LEACHM model predicts that approximately 25% of the average annual rainfall of 776 mm would run off from the sugarcane crop. Of this 194 mm of runoff, approximately 48 mm of runoff, can be assumed to be captured and returned as irrigation water. Hence, approximately 146 mm of runoff (194 mm less 48 mm), or approximately 20% of the average rainfall, is predicted to leave the farms in average years. A similar proportion is predicted for the areas occupied for road and drainage infrastructure.

The net effect on surface water as a result of the proposed development proceeding would be an increase in the volume of runoff reaching streams and rivers over a typical wet season. In the natural state, there is approximately 5% of rainfall (40 mm) run off from the black-soil plains. Hence, on average, the increase in run off would be approximately 106 mm, about 37 GL/a from the total Project Area, resulting in an annual flow increase of about 25% (based upon median flow of 150.5GL/a given in Table 5.4) in the lower reaches of the Keep River.

The timing of runoff flows leaving the Project Area would also change following development due to the cropped areas entering the wet season in a moist state and the

improved efficiency of the drainage infrastructure. The magnitude of this change would vary during the wet season as a result of natural variation in rainfall intensity and the operation of the first-flush runoff capture systems. However, assuming that the first 50–100 mm of rainfall is currently required to ‘wet up’ the black-soil plains prior to runoff occurring, it is probable that in some seasons the runoff from the cropped areas would occur around one month earlier than is currently the case.

It is noted that there is a high degree of natural variability of surface-water flows due to the variable nature of rainfall in the region. The changes to flows in the Keep River and Border Creek brought about by improved drainage of the Project Area, as described above, are unlikely to be significant in all but extreme years as they would be within the range of natural variability for these watercourses. Changes to flows in drier years would be the most significant and, at these times, the higher and earlier flows from the Project Area are considered likely to be beneficial to the environment supported by these watercourses.

5.4.3 Alteration of dry season flow patterns

Management of water levels within irrigation channels would be via automated gates controlled from a centralised control centre utilising a SCADA system. This system would be more efficient at minimising spillages than a manual control system. Nevertheless, some intermittent releases of good quality water may occur to the drainage system during maintenance activities such as cleaning of weed-control structures, and periodic draining of channels to facilitate killing of weeds through exposure to the sun.

Releases of water from irrigation channels could also occur during emergency events such as channel-control gates jamming, software failure, or the system being struck by lightning. Any of these events may cause water to back up in channels and overflow to the drainage system, but in a controlled manner. During such an event, the electronic SCADA system would provide warning signals to supervisors. Field crews would then be notified and manual control of gates would be employed until the emergency event had been rectified.

The capture and reuse of tailwater are expected to virtually eliminate discharges from farming areas to the drainage system in the dry season. This would be consistent with the existing natural conditions where surface runoff does not occur from the plains area during the dry season. Tailwater discharges would only occur during periods of mechanical or other operational failures of the tailwater return systems. The magnitude of the releases in these circumstances would be restricted by storage of tailwater in the first-flush storage system and by the irrigation water supply being terminated upon detection of any problems with the tailwater return system.

5.4.4 Influence of groundwater management strategies

Groundwater levels throughout the Project Area would be managed to ensure waterlogging of cropped areas does not occur (Chapter 6 refers). A consequence of this management would be that groundwater would generally be maintained at sufficiently low levels to avoid rising groundwater causing any incremental permanent base flow in watercourses throughout the Project Area.

5.5 WATER QUALITY ISSUES

Water quality issues may arise from a number of areas, as follows:

- ground-disturbing activities during construction;
- farm operations, including possible movement of farm chemicals beyond the boundaries of the cropped areas;
- discharges from the raw-sugar mill of cooling water and treated process water;
- maintenance operations in the irrigation supply channels and balancing storage dams for the control of aquatic weeds;
- in the longer term, possible discharges from the groundwater management system comprising groundwater that is too saline for use in irrigation systems.

These issues are discussed further below, with specific reference to the management measures proposed to mitigate water quality impacts in the receiving waters. Predicted changes to water quality in the Keep River and the water quality monitoring programme proposed for the Project are described in Section 5.6 and Appendix O.

5.5.1 Construction activities

Construction operations would include the clearing and planing of farm areas and extensive earthworks associated with construction of the irrigation, drainage and road infrastructure. The movement of construction machinery over these areas during the wet season would be extremely difficult; hence construction of these components of the Project would be restricted to the dry season, usually between the months of May to October, inclusive.

Construction activities would also be associated with the raw-sugar mill. These construction activities would commence with the establishment of an all-weather access road to allow uninterrupted construction during the wet season.

The primary water quality issue during construction would be the control of sediment that would otherwise enter waterways. Management of sediment during construction would involve a combination of the following measures:

- wherever practicable, restricting ground-disturbing operations to the dry season;
- restricting ground-disturbing operations to the minimum area required to facilitate construction;
- collecting and storing for future use any topsoil from areas to be disturbed;
- installing and maintaining temporary sediment traps downstream of any areas to be disturbed;
- progressive clearing, developing and rehabilitating, wherever possible using locally won topsoil, of any areas that are no longer going to be disturbed.

Monitoring of water quality in the receiving watercourses would also be undertaken during construction.

5.5.2 Farm operations

Management measures would be provided to counter each of the potential mechanisms that exist for the movement of agricultural chemicals off the farms and into the environment. Research into these mechanisms has been undertaken previously for pesticides, particularly endosulfan from cotton farms (Schofield et al. 1998). Although endosulfan is not used on sugarcane, the transport mechanisms identified by the research are useful for devising the management measures proposed for the cane fields and for other crops that may be grown in the Project Area. The management measures proposed for each transport mechanism are described below in decreasing order of importance to off-farm impacts.

Surface water and suspended sediment

Stormwater runoff from irrigation farms can transport eroded soils, nutrients and pesticides. Installation of adequately sized first-flush runoff storages minimise these impacts by trapping and reusing some of these elements on the farm. For the Project, the following approach representing current best practice in farm water management (adopted from a review of the Environmental Protection Authority of New South Wales 1995 and Barrett et al. 1991 as developed by the NSW State Pollution Control Commission, the Queensland Department of Environment and Heritage, and the Department of Primary Industries) would apply;

- Irrigation tailwater return systems would be provided to all cropped areas.
- A first-flush storage capacity of 12 mm of rainfall runoff would be provided to all sugarcane farms.
- A first-flush storage capacity of 25 mm of rainfall runoff would be provided to any farms using endosulfan or any other chemicals perceived to be of high risk to the aquatic environment.
- Collected irrigation tailwater and first-flush stormwater would be reused for irrigation.
- Fertilisers or chemicals would not be applied to cropped areas when the first-flush basin capacity is not available.
- The storage capacity of the first-flush basin would be maintained through regular inspection and removal of sediment.

Sediment retrieved from the first-flush systems would be spread on the cropped areas.

Spray drift

Spray drift is the airborne movement of fine spray droplets away from the crop being sprayed. Results of research throughout Australia indicate that spray drift from the aerial application of pesticides on cotton is potentially a significant contributor to riverine contamination (Schofield et al. 1998).

Sugarcane has a minimal requirement for pesticides to grow successfully in the ORIA (Chapter 2 refers). However, the management measures that would be adopted for the Project to minimise the effects of any spray drift would be as follows:

- adoption, where appropriate for the crops being grown, of the integrated pest management strategy developed by AGWEST for ORIA Stage 1 (Section 2.3.1 refers) to minimise the amount of pesticides used;

- strict control on the use of pesticides, including mandatory adoption by all farmers of the spray calendar developed annually for ORIA Stage 1;
- minimisation of the use of aerial spraying, by using tractor-based spraying to the maximum extent possible;
- avoidance of unsuitable weather conditions such as surface temperature inversions and unstable conditions during aerial spraying whenever possible;
- utilisation of a large droplet size settings for spray equipment during aerial spraying;
- a requirement that all commercial spray operators be accredited to a national registration programme.

In addition to the above measures, it should be noted that the Project layout includes the provision of conservation areas between cropped and riparian areas (Chapter 10 refers). The width of these areas would be determined on a case by case basis, but as a minimum would be:

- 250 m from the incised channels of rivers;
- 250 m from the outer edge of the riparian zone of wetlands;
- 100 m from the incised channels of significant creeks.

Airborne dust

Soil particles on which pesticides can be deposited can also be subject to suspension in the atmosphere by wind and by activities such as tillage and vehicular traffic. Research has clearly shown that dust movement on farms can relocate pesticides (Schofield et al. 1998). However, this pathway is likely to be far less important than spray drift, in the off-farm aerial transport of pesticides.

Management measures that would be adopted for the Project to minimise the effects of airborne dust include:

- provision of dedicated on-farm access tracks that would not have agricultural chemicals applied directly to them;
- wherever possible, adoption of ‘minimum tillage’ farming practices.

Volatilisation

Pesticides can volatilise from plant surfaces, the soil surface, from within the soil pore spaces and from pesticides adsorbed on to soil particles. Volatilisation is affected by the saturation vapour pressure of the pesticide, adsorption to substrates, wind velocity, temperature, soil water content, pesticide diffusion and advection through the soil, and the application method (Schofield et al. 1998). Research has established the potential of volatilisation of pesticides to contaminate nearby rivers. However, the contribution from volatilisation is likely to be significantly less than the other transport mechanisms described above. Management would involve minimising the use of pesticides by adoption, wherever possible, of the integrated pest management strategy.

5.5.3 Sugar mill effluents

The raw-sugar mill would produce two effluent streams: a cooling water stream sourced and returned to the irrigation supply system, and a process effluent stream. Each of these streams would only occur during the crushing (dry) season.

The cooling water stream would consist of approximately 288 ML/d of irrigation water sourced from the irrigation supply system upstream of the sugar mill. An equivalent volume, with its temperature elevated by some 3°C would be returned to the irrigation supply system downstream of the sugar mill.

The process effluent stream would be produced at a rate of about 4.8 ML/d during the crushing season. Because of its high BOD it would be treated in an activated sludge treatment plant to achieve a BOD level of less than 20 mg/L. The effluent would then be utilised on sugarcane fields where it would replace some of the crop's irrigation water requirement.

5.5.4 Weed control in the irrigation channels

Control of aquatic weeds in the irrigation channels and balancing storage dams would be by a combination of mechanical weed removal and periodic dosing with a chemical such as acrolein. The latter is currently used for the control of aquatic weeds in the irrigation channels in ORIA Stage 1.

Chemical management would be in accordance with best-practice procedures as outlined below:

- emptying the channel, locking offtakes, erecting warning signage and notifying farmers prior to injection of the chemical;
- releasing a known flow of water to obtain a water depth of approximately 0.5 m into the channel and releasing the chemical from a controllable release point to maintain an initial concentration (15 ppm in the case of acrolein);
- releasing a marker dye to denote the chemical front;
- shutting flow to the channel and holding the chemical in the channel for a minimum of forty-eight hours before diluting by release of additional water and use of the water for irrigation;
- monitoring of watercourses downstream of the Project Area for acrolein and if detected, review the above procedure in conjunction with the Water and Rivers Commission and the DLPE

5.5.5 Groundwater disposal

Chapter 6 describes the groundwater management strategy that would be implemented as part of the Project. This strategy makes provision for the future extraction of groundwater by bores in order to control groundwater levels.

Disposal of the extracted groundwater would preferentially be into the irrigation channels, to supplement the water obtained from Lake Kununurra. However, it is anticipated that some of the groundwater may be too saline for use in the irrigation system and may therefore require separate disposal. At this stage, Project planning assumes that groundwater

unsuitable for use as irrigation water would be collected by pipelines and discharged into the tidal reaches of the Keep River and Sandy Creek. The groundwater collection and disposal system is described further in Chapter 6.

5.6 PREDICTED CHANGES TO WATER QUALITY

5.6.1 Water quality in the Keep River

The potential for the Project to result in elevated nutrient levels in receiving waters has been assessed by the comparison of nutrient levels in drains from ORIA Stage 1, with recorded levels in the Keep River (Table 5.8 refers). The comparison, when the proposed water management practices for the Project are taken into account, would imply a low potential for impact on the nutrient levels in receiving waters. In fact, only a minor reduction in the concentrations of nutrient runoff recorded from farms in ORIA Stage 1 would be required to reduce nutrient levels to levels currently occurring in the Keep River.

Table 5.8 Comparison of nutrient levels in ORIA Stage 1 drains and the Keep River

Nutrient	Irrigation runoff†	Rainfall runoff†	D4 drain*	Keep River
Total nitrogen (mg/L)	0.48	0.68	0.60–1.13	0.28–0.36
Total phosphorus (mg/L)	0.06	0.12	0.21–0.23	0.01–0.54

* Sampling September 1997 (Doupé et al. 1998).

† Mean concentrations for 1996 (Sinclair Knight Merz 1998).

There would be a low requirement for pesticide use in the Project Area. The majority of the farmed area would be devoted to sugarcane, a crop that has a low requirement for pesticides, and no requirement for endosulfan, to grow successfully in the ORIA.

Crops other than sugarcane could possibly be grown on areas farmed by independent farmers. Experience in ORIA Stage 1 has indicated that these other crops may require a greater use of pesticides than sugarcane, and possible use of endosulfan. Endosulfan is extremely toxic to some aquatic fauna species. The ANZECC (1992) recommendation for the upper limit of endosulfan concentration in the aquatic environment is 0.01 µg/L.

Water quality sampling undertaken in September 1997 in drains discharging from ORIA Stage 1 indicated endosulfan levels in the range of less than 0.001–0.025 µg/L (Doupé et al. 1998). Other sampling has indicated endosulfan concentrations in the ORIA Stage 1 drains in the range of 0–1.1 µg/L (H.G. Gardiner & Associates 1998). The high level was recorded only once, with the majority of levels in the ORIA Stage 1 drainage system ranging from undetectable to 0.2 µg/L.

The potential endosulfan concentrations in the Keep River have been assessed by assuming endosulfan concentrations in the drains of the independent farming area of the Project would be similar to those monitored in the drains of ORIA Stage 1. This assessment has ignored the beneficial effects of the water management measures proposed for the Project, and is therefore considered conservative. It is predicted that endosulfan concentrations, following dilution with Keep River flows, may be within the range 0–0.04 µg/L and generally less than 0.006 µg/L.

As a consequence of the predicted endosulfan concentration being of similar magnitude to the recommended limit, a precautionary approach of adopting interim restrictions is proposed on the use of endosulfan in the Project Area.

The interim restrictions would require each application of endosulfan to receive prior approval from the Environmental Management Entity that would be established in conjunction with the Project (see Chapter 16). The interim restrictions would include monitoring of farm drains, tailwater return systems and drainage flows to confirm the effectiveness of the proposed management measures.

The interim restrictions on the use of endosulfan in the Project Area would be in addition to other commitments made in this ERMP/draft EIS with regard to the use of pesticides. Modification of the interim restrictions, if supported by monitoring results, would be made via the periodic reviews and updating of the Project's EMP.

5.6.2 Water quality in Sandy Creek

Sandy Creek currently drains approximately half of the Keep River Plain and this would continue following Project development.

The potential for the Project to impact upon water quality in Sandy Creek would be less than the generally acceptable levels predicted for the Keep River as described in the previous section. The reasons for this are as follows:

- A smaller proportion of the Sandy Creek catchment (about 4%) would be developed for farmland than for the Keep River (about 6%).
- Drainage discharges from the farm development area would be at, or below, the tidal limit on Sandy Creek, thereby providing additional dilution and flushing of drainage flows.
- It is likely that all the farmland on the Keep River Plain would be devoted to growing sugarcane, thereby avoiding the pesticide issues associated with the cultivation of other crops.

5.6.3 Water quality monitoring

Water quality monitoring would form an important component of the environmental management programme proposed for the Project. Data collected by the monitoring programme would be assessed regularly in conjunction with management practices with the aim of minimising impacts on the receiving environment.

The water quality monitoring programme would be developed in detail as part of the Project's EMP and comprise chemical and physical parameters as well as long-term monitoring of biological impacts on fish and macro-invertebrates (see Appendix O). At this stage it is proposed that the water quality monitoring programme would be implemented by the Environmental Management Entity (Chapter 16) that would be established as part of the Project, and as a minimum involve regular sampling and analysis of the parameters nominated in Table 5.9.

Table 5.9 Outline water quality monitoring programme

Parameter	Location							
	Farm soil	Farm drains	Tailwater dams	Drainage channels	Border Creek	Keep River*	Sandy Creek*	Irrigation channels
Flow	–	–	–	✓	✓	✓	✓	✓
Suspended solids	–	✓	✓	✓	✓	✓	✓	✓
TDS	–	✓	✓	✓	✓	✓	✓	✓
Nutrients	–	–	✓	✓	✓	✓	✓	✓
Insectides	✓	–	✓	✓	✓	✓	✓	–
Herbicides	✓	–	–	✓	✓	✓	✓	✓
Turbidity	–	✓	✓	✓	✓	✓	✓	✓
Heavy metals	✓	–	✓	–	✓	✓	✓	–
Chlorophyll <i>a</i>	–	–	–	–	✓	✓	✓	✓
Dissolved oxygen	–	–	–	–	✓	✓	✓	–
Erosion and sedimentation	–	–	✓	✓	✓	✓	✓	✓
Biological impacts	–	–	–	–	✓	✓	✓	–

✓ Indicates regular sampling and analysis.

– Indicates no sampling.

* Includes upstream and downstream of Project Area.

6 Groundwater

This chapter addresses groundwater issues associated with the Project. It describes the features of the regional geology and existing groundwater environment (hydrogeology) together with measures proposed to manage impacts on a sustainable basis. Extensive numerical modelling was used to develop the groundwater management strategy for the Project and to quantify the range of likely impacts. This modelling is also described, with reference to technical appendices where appropriate.

6.1 BACKGROUND

The groundwater environment beneath the Project Area is currently considered to be in equilibrium, with groundwater levels reflecting a balance between geological formation and recharge from the surface. Development of the Project Area for broad-acre flood irrigation would change the hydrological cycles on the land surface of the Project Area. This would result in a change in the rate of groundwater recharge and, hence, a change in groundwater levels.

Currently the land surface is dry for approximately seven to eight months of the year during the dry season; this results in extensive cracking of the surface soils. During the following wet season, the black soils absorb water and expand, closing the cracks and thereby establishing a relatively impermeable surface layer. At this time the black-soil plains of the Project Area are characterised by free water on the surface due to a combination of intensive rainfall, poor drainage and the low rate of infiltration of water into the ground.

Net evaporation rates are high in the region, averaging about 2,100 mm/a, far in excess of the average rainfall of 776 mm/a. Tree coverage on the black-soil plains is extremely limited; however, a dense coverage of native grasses (see Chapter 8) quickly establishes itself during the wet season and, through evapotranspiration, these grasses add considerably to the rate of soil moisture loss. Although limited, the available evidence suggests that the rate of soil moisture loss is sufficient to result in the black-soil plains currently contributing little or no recharge to underground aquifers.

As mentioned earlier, the development of the black-soil plains for broad-acre flood-irrigated agriculture would change the hydrological cycles on the land surface. It would do this in a number of ways, as outlined below:

- Irrigation water would be applied to the land surface during the dry season, and occasionally during dry periods in the wet season, with the rate of application managed to satisfy the evapotranspiration rate of the crop.
- Drainage infrastructure construction and grading of the farm units would provide an efficient means of stormwater removal.

- Irrigation channels and balancing storage dams would be constructed that would be permanently filled with water.
- The native vegetation cover would be replaced with perennial crops, predominately sugarcane.

The above changes are expected to result in an increased rate of water infiltration (known as accessions) to underlying aquifers and a consequential rise in groundwater levels. The rate of groundwater rise and the need for groundwater management measures would vary with a number of factors, including the magnitude of the accessions to groundwater, the initial depth of groundwater from the surface, and local hydrogeological features. Agricultural activities are generally not affected unless groundwater levels are within approximately 2 m of the surface, a condition referred to as waterlogging. However, management measures are generally required for groundwater within 5 m of the surface, particularly if the groundwater is saline or the rate of groundwater rise is sufficient to cause waterlogging in a short timeframe.

The following sections describe the existing local groundwater environment, changes predicted as a result of the proposed development proceeding, and how groundwater would be managed to enable long-term use of the Project Area for irrigated agriculture.

6.2 REGIONAL GEOLOGY

The regional geology of the Project Area has been described by Moray and Beere (1988). Geological descriptions of portions of the area are presented in Laws (1991), Sweet et al. (1974) and Whitehead and Fahey (1985). The Water and Rivers Commission and the Department of Lands, Planning and Environment have also compiled an interpretation of the geology and hydrogeology of the ORIA. An extract of this interpretation covering the Project Area is provided in (Appendix I). The following sections describe elements of the regional geology of relevance to the Project.

6.2.1 Basement geology

Weaber Plain

The Weaber Plain is bounded by outcropping basement rock to the north (Weaber Range) and the south (Pincombe Range and Sorby Hills). In the south-west, the plain is bounded by basement rock, with the exception of the Cave Spring Gap region.

Underlying most of the plain is a mixture of Precambrian to Permian units of varying lithology, including sandstone, limestone, shale and conglomerate. Through Cave Spring Gap, the basement rocks consist of Precambrian sandstone and shale of the Bastion Group. A major basement inlier within the plain, Folly Rock, is composed of Proterozoic sandstones of the Carr Boyd Group. North of Folly Rock, the basement changes to Carboniferous Milligan Formation shale.

In general, Palaeozoic sediments underlie the alluvial sequence through the northern portion of the plain while in the south, the basement is a thin sequence of Devonian limestone and sandstone overlying Cambrian Antrim Plateau Volcanics.

Knox Creek Plain

The geological strike along the Knox Creek Plain is dominantly north–south, consistent with the major axis of the plain. The plain is largely underlain by the Milligan Formation shale, incised by a palaeochannel and locally overlain by calcrete. To the west and north, the basement units underlying the plain include the Carboniferous Burt Range Formation, Septimus limestone, and well-bedded limestone and sandstone of the Devonian-Carboniferous Button Beds. Other units of the Landfield Group may be present. To the east, the plain is underlain by undifferentiated Permo-Carboniferous sandstone.

Knox Creek is generally fully contained within alluvial sediments and does not incise into the basement, except for an area of limited extent in the north.

Keep River Plain

The basement rock underlying the Keep River Plain is, for the most part, undifferentiated Permo-Carboniferous sandstone, with the exception of the southern portion of the plain, where the basement comprises Carboniferous shale. Alluvial sediments have incised into, and been deposited upon, both of these units.

6.2.2 Alluvial sediments

Weaber Plain

Alluvial sediments comprise the upper 5–35 m of the Weaber Plain (Nixon 1997b, 1997e). These sediments are presumed to have been deposited by the Ord River, when it is postulated to have flowed to the north-east beneath the Weaber Plain and then roughly along the course of the present-day Keep River. The sequence of sediments includes a basal coarse-grained unit (palaeochannel) deposited by the main river channel. Despite being restricted to a narrow extent through the plain these palaeochannel sediments are of considerable importance to the hydrogeology. The alluvial sequence becomes progressively finer upwards across the entire plain. However, little is known in detail of the variability of these sediments as the drilling that has been undertaken is sparse in relation to the area being considered and there is little correlation between boreholes for coarser or finer units (Nixon 1997a, 1997b, 1997d, 1997e).

Knox Creek Plain

The alluvial deposition within the Knox Creek Plain differs in part from that in the Weaber Plain by the poorer definition of the palaeochannel (although the palaeochannel is continuous beneath the eastern side of the plain) and the finer nature of the sediments. The alluvial sediments in the paleochannel become progressively deeper and broader in the northern part of the plain. A fining upward sequence is postulated, with the basal part of the sequence being finer than that of the Weaber Plain.

Calcrete is found beneath the western part of the Knox Creek Plain overlying the palaeochannel sediments or directly upon the basement complex. The calcrete varies greatly in width and thickness, to as much as 4 km wide and 15 m thick.

Keep River Plain

It has been postulated that the ancient course of the Ord River passed through the Weaber Plain and into the Keep River Plain. This river incised a deep channel, which has subsequently been infilled with the Tertiary and Quaternary sediments to form a palaeochannel. In the west, the palaeochannel is up to 35 m deep, with a coarse basal unit approximately 10 m thick. This is the downstream continuation of the palaeochannel as described for the Weaber Plain. Above the coarse palaeochannel sediments is a finer sequence with clayey sand at the base, fining upwards to a silty clay near the surface. Drilling by the Power and Water Authority has delineated the palaeochannel extent and thickness (Humphreys et al. 1995).

6.3 REGIONAL HYDROGEOLOGY

6.3.1 Groundwater flow

Weaber Plain

The general flow gradient beneath the Weaber Plain is from the west to the east (Appendix I). Elevated groundwater levels exist in the Cave Spring Gap as a result of the existing irrigation activities in ORIA Stage 1. The groundwater elevation just east of the current irrigation area is around 22–26 m AHD, which is around 5 m below the ground surface. From here groundwater flow is through the Cave Spring Gap and on to the Weaber Plain. The elevation of the water-table decreases to between 5 m AHD and 10 m AHD in the vicinity of Folly Rock. This is some 20 m below surface, but may be up to 35 m below ground in some areas. In the north of the plain, near Point Spring, the groundwater elevation is higher than on the central part of the plain. A groundwater elevation at around 17 m AHD has been recorded (Nixon 1997a, 1997e), and it has been postulated that the broad areas of sandy soils in the Border Creek region (north of the Weaber Plain) are contributing some recharge to the sediments underlying the plain. This is also an area of relatively shallow bedrock, which may be contributing to the higher groundwater levels. The water-table associated with Point Spring occurs within the bedrock system and is entirely separated from the alluvial sediments.

East of Folly Rock, the groundwater level is at around 5 m AHD and remains above 3 m AHD to the eastern end of the plain. This is approximately 15–20 m below the general level of the plain. The incised valley of the Keep River is at approximately 12–14 m AHD, approximately 10 m above the groundwater level. There is no evidence of groundwater interaction with the river in this area, although data are poor. Groundwater recharge across the plain is considered to be very low. The existing groundwater gradient appears to be largely controlled by the palaeochannel throughflow from the Ivanhoe Plain and by recharge from the Border Creek area.

In the southern part of the plain, near Sorby Hills, extensive drilling for mining exploration has shown the basement rocks in this area to be limestone and dolomite, which have significant groundwater storage potential. It has been assumed that there is little, if any, upward movement of groundwater from the basement rocks into the alluvial sequence. It is more likely that groundwater in this area moves from the alluvial sediments into the bedrock.

Knox Creek Plain

Groundwater flow beneath the Knox Creek Plain (Appendix I) appears to be to the north, following the paleochannel beneath the eastern portion of the plain. In the southern part of the Knox Creek Plain the groundwater levels are significantly higher than those in the northern part of the plain, by some 8 m. Groundwater flow in the southern section of the plain is to the north-west, from the Northern Territory section to Western Australia. Groundwater levels range from around 7 m AHD down to 3–4 m AHD where the Knox Creek Plain joins the Weaber Plain. This is approximately 10–15 m below the ground surface.

Recent drilling undertaken for the Project has shown that Milligan Lagoon is a localised perched aquifer formed by a clay layer that occurs to a depth of up to at least 9 m below ground. The regional water-table is some 20 m below the level of the lagoon. The lagoon is fed by rainfall and runoff, and possibly by minor groundwater inflow from the hills to the west.

Knox Creek and its tributaries are not considered to be part of the groundwater system as their bed levels are some 10 m above the current groundwater level. However, it is likely that these creeks are important groundwater recharge features during the wet season due to the general sandy nature of their bed profiles.

Keep River Plain

Groundwater flow beneath the Keep River Plain (Appendix I) is a continuation of the flow coming from the Weaber Plain, with groundwater elevations in the west of the Keep River Plain at or around the level of those in the Weaber Plain. Groundwater flow is then generally to the north-east, along the line of the plain with a smaller component to the north west, from the higher Permo-Carboniferous sandstone towards the alluvium.

The Keep River and Sandy Creek are in connection with the alluvial sediments along their length and, where these are tidal or semi-tidal, they provide a natural tidal control on groundwater levels. Beneath the Keep River Plain the basement rocks are in part Permo-Carboniferous sandstone, which is highly permeable and contains good quality groundwater. In the eastern end of the plain it appears that the permeable Permo-Carboniferous sandstone and the incised palaeochannel sediments comprise a single hydrological unit, although the nature, extent and degree of connection between the two systems have yet to be confirmed.

6.3.2 Groundwater quality

Regional groundwater quality, as mapped by the Water and Rivers Commission and the Department of Lands, Planning and Environment, is shown in Appendix I and described further below.

Weaber Plain

Groundwater quality beneath the Weaber Plain is generally fresh to slightly brackish (Nixon 1997a, 1997b, 1997e). Groundwater beneath the Cave Spring Gap appears to be fresh, around 1,000 mg/L TDS (Nixon 1997d). It is not clear if this level of salinity is influenced by accessions from current irrigation in ORIA Stage 1. Throughout the southern and central parts of the Weaber Plain, groundwater salinity ranges from 70 mg/L TDS to 2,600 mg/L TDS. At the northern edge of the plain the groundwater salinity appears to be associated

with bedrock highs, although water analyses from Point Spring (Nixon 1997e) indicate that the groundwater emanating from bedrock in that region is of relatively good quality (50 mg/L TDS).

Knox Creek Plain

In the Knox Creek Plain the groundwater salinity ranges from 60 mg/L TDS to 20,800 mg/L TDS but in general is around 1,000 mg/L. The salinity is a sodium chloride type with elevated sulphate and bicarbonate.

Based on airborne electromagnetic studies conducted jointly by the Western Australian and Northern Territory Governments, there is considered to be a significant difference in the groundwater quality in the west of the plain compared with that in the east, reflecting the nature of the bedrock. Where alluvial sediments overlie the Milligan Formation shale the groundwater appears to be more saline than the groundwater overlying the permo-carboniferous sandstone. Delineation of the contact between these units and the potential impact on groundwater quality are discussed in Chin et al. 1997.

Keep River Plain

The groundwater salinity beneath the Keep River Plain varies greatly, ranging between 100 mg/L TDS and 51,000 mg/L TDS across the plain (Humphreys et al. 1995). The Department of Lands, Planning and Environment has identified six main salinity zones, based on airborne electromagnetic surveys and inferred basement geology. From west to east across the plain, the groundwater salinity changes from moderate to high (up to 20,000 mg/L TDS) adjacent to the tidal reaches of the Keep River, through a low salinity region (salinity expected to be less than 2,000 mg/L TDS) and then into a more saline region, which is within the influence of the tidal reaches of Sandy Creek.

The groundwater chemistry is dominated by sodium chloride ions, although bicarbonate concentrations are also commonly high. Nitrate levels are generally below 1–2 mg/L.

6.4 MANAGEMENT OF ACCESSIONS TO GROUNDWATER

6.4.1 Infrastructure

Irrigation and drainage infrastructure, as required by the Project, would contribute accessions to groundwater to varying degrees.

The irrigation water supply infrastructure, comprising main and secondary supply channels and balancing storage dams, would be permanently filled with water whereas the drainage water collection channels would only convey water intermittently, predominately following rainfall. Accordingly, the methods of managing accessions to groundwater from this infrastructure would vary as outlined below:

- Irrigation channels would be constructed with a low permeability clay lining so that the rate of infiltration from the channel would be less than 2 mm/d. The clay lining would consist of compacted *in situ* clay where the *in situ* material is considered appropriate, or otherwise of compacted clay sourced from nearby borrow pits or other excavations necessary for infrastructure construction. Construction standards would be monitored to

ensure that material selection and compaction standards are sufficient to restrict the maximum infiltration rate to the standard nominated above.

- Balancing storage dams would be sited in areas where the dominant surface soils are of Aquitaine clay. Aquitaine clay is the least permeable soil type occurring in the Project Area. As with the irrigation channels, construction standards would be monitored to ensure that the rate of infiltration is less than 2 mm/d from these balancing storage dams.
- Drainage channels would be designed to be broad and shallow to take advantage of the naturally occurring soil conditions; these consist of lower permeability clays nearer the surface, overlying soils of increasing permeability with depth. Sections of channels that traverse highly permeable soils would be modified to incorporate a lining of compacted clay.

The above measures represent current best-practice construction standards for irrigation infrastructure, and modern quality assurance procedures would be adopted during construction to ensure that the design intent is achieved in practice. As a minimum, these procedures would include extensive testing of soil properties to guide material selection and *in situ* testing of compaction levels prior to the works being accepted as complete. Soil type and degree of compaction are the main factors that determine a soil's capacity to minimise the infiltration of water.

6.4.2 Cropping areas

Sugarcane has a relatively high irrigation water requirement. Nearly all of this demand is needed to offset crop evapotranspiration, and irrigation schedules developed to satisfy this requirement only would eliminate accessions to groundwater. However, as described below, there are a number of reasons why it is neither practical nor desirable to eliminate all accessions to groundwater.

Some accessions to groundwater would be required to remove salts from the root zone of the crop that would otherwise accumulate from the consistent application of irrigation water, even from the low-salinity (160 mg/L TDS) water sourced from Lake Kununurra.

Also, as described in Chapter 4, some leaching of water through the soil profile would be desirable as a means of managing potential sodicity effects with the soils of the Project Area. Sodicinity is a complex chemical reaction involving the exchange of sodium and calcium ions. In extreme cases sodicity can lead to precipitation of salts in soil voids, loss of soil structure and loss of agricultural viability. Maintaining a modest leaching fraction (up to 100 mm/a) is expected to mitigate the potential for sodicity effects.

Another factor that would influence accessions to groundwater is rainfall, particularly during the wet season. In the natural situation the onset of the wet season follows a long dry period that invariably leaves the upper soil profile dry. This situation would change following project development as the cropped areas would be irrigated during the dry season and the soils at the onset of the wet season would be in a moist condition. It is likely that rainfall during the wet season would be available immediately to infiltrate the soil profile, with the quantity of infiltration dependent upon the magnitude and timing of rainfall events.

Numerical modelling has been used to quantify the infiltration of rainfall and irrigation water from the root zone of the crop to groundwater. This modelling, described in Appendix H, utilised an unsaturated flow infiltration model—the LEACHM model (Hutson and Wagenet

1992). LEACHM is a water balance model that is able to evaluate water movement through unsaturated soils as well as water uptake by crops.

The results of the LEACHM modelling show that the rate of accession to groundwater from cropping areas would be in the range 54-119 mm/a and that for average meteorological and soil conditions the rate is expected to be 94 mm/a. For groundwater management planning purposes an average rate of 100 mm/a has been adopted for the Project. It is noted that variations in soil conditions would result in local variations in the groundwater accession rate. However, regional changes in groundwater levels would be representative of accession rates over large areas, justifying the use of an average rate for the current planning purposes. Further justification for the approach and accession rates adopted for the Project has been provided by recent studies by Sinclair Knight Merz (1998) that derived an average rate of accession to groundwater from cropped areas in ORIA Stage 1 of approximately 100 mm/a in 1996.

6.5 GROUNDWATER MANAGEMENT STRATEGY

6.5.1 Groundwater modelling

The potential impacts on the groundwater environment were assessed using a numerical groundwater model developed using the USGS MODFLOW software package and the hydrogeological database held by the Water and Rivers Commission and the Department of Lands, Planning and Environment. The model, described in Appendix I, predicts groundwater levels with time on the basis of information supplied regarding geology, infiltration from the surface and groundwater abstractions by bores.

The most critical parameter of the groundwater model—the rate of aquifer recharge or accession rate—was assumed to be 2 mm/d (the maximum value adopted for design) from the irrigation infrastructure (see Section 6.4.1) and 100 mm/a from the cropped areas (see Section 6.4.2).

The USGS MODFLOW model was used as a design tool as well as for predicting groundwater response for the proposed groundwater management strategy. The range of model runs performed is outlined in Appendix I. Many of the model runs, including the proposed groundwater management strategy, involved the use of bores to partially dewater aquifers underlying the Project Area. In these cases the modelling was undertaken assuming a generally uniform distribution of the dewatering bores in areas where aquifers were known to have sufficient permeability to allow long term pumping.

Further exploration drilling would be completed and trial production bores installed and tested prior to the commencement of full-scale irrigation. The necessary optimisation studies for the dewatering bore system would then be undertaken.

All of the modelling scenarios assumed a period of fifty years to represent long-term operation of the Project. This period reflects a sensible limit on the use of the available data and the accuracy of the modelling based upon these data. Sustainability of irrigated agriculture in the Project Area for periods longer than 50 years was assumed to be demonstrated if the rate of groundwater rise at 50 years was small and within the accuracy normally expected of groundwater modelling. This situation was achieved for an accession rate of 100 mm/a from the cropped areas by running the model with progressively more dewatering bores and then optimising the time of commencement of pumping and the

pumping rate. The proposed groundwater recovery system is described further in Section 6.5.2.

It is noted that none of the modelling scenarios included the effects of field drains that may be used as a groundwater management measure in the future. This was a deliberate action as the model was used to identify the extent of the cropped area that is likely to require this form of groundwater management. The result of omitting the field drains from the modelling scenarios is that the predicted groundwater levels for the proposed management strategy (see Section 6.5.3) continue to rise, albeit slowly, in some areas after fifty years.

Field drains consist of a series of perforated pipes laid below the surface that would allow the entry and collection of groundwater, however, they are only effective when groundwater levels are at or above the level at which the drains are laid.

6.5.2 Groundwater recovery and disposal

The proposed groundwater management strategy would require the direct control of groundwater levels by the long-term use of dewatering bores and, to a lesser extent, field drains.

Dewatering bores at depths of 10–30 m would extract groundwater from the permeable palaeochannels that underlie much of the Project Area. The optimal locations for the dewatering bores (ultimately numbering about thirty) would be determined following further field investigations. Current planning assumes that the dewatering bores would be uniformly spread over areas underlain by palaeochannels or other permeable strata, with minor variations in location made to accommodate infrastructure and farm unit boundaries. A conceptual layout of dewatering bore locations and buried collector pipelines are shown in Figure 6.1.

The results of the groundwater modelling undertaken for this Project indicate that dewatering bores and field drains may only need to be operated after approximately ten years of cropping; even after that time their installation could be phased in over a number of years. Groundwater collected by the dewatering bores and field drains would therefore be variable in time both in terms of quantity and quality, with the latter initially being highly dependent upon existing groundwater quality.

Collected groundwater would initially be disposed of as irrigation water, following dilution in the irrigation channels with water sourced from Lake Kununurra. In some areas the quality and quantity of the extracted groundwater would be such as would allow this practice to be the long-term method of disposal. However, project planning is currently based upon the conservative assumption that, in the long term, all extracted groundwater may be too saline for re-use as irrigation water and would therefore require disposal to the tidal sections of the Keep River and Sandy Creek downstream of the Project Area. These receiving waters would be marine (about 35,000 mg/L TDS). The quantities and likely range of water quality for the extracted groundwater, based upon this assumption, are given in Table 6.1.

Table 6.1 Estimated long-term dewatering rates

Location	Approximate quantity (ML/a)	Likely level of salinity (mg/L)	Likely discharge location
Weaber Plain	8,600	2,200–2,600	Tidal section of Keep River
Knox Creek Plain	1,800	2,200–13,000	Tidal section of Keep River
Keep River Plain	1,100	2,200–20,000	Tidal section of Keep River and Sandy Creek

The collector pipelines would be fabricated from corrosion resistant polyethylene or PVC. They would also be buried in order to minimise the risk of damage, and wherever possible, follow roads or tracks in order to facilitate access for maintenance.

The potential impacts arising from the discharge of collected groundwater is discussed in Section 10.4.5

6.5.3 Predicted changes to groundwater levels

The USGS MODFLOW groundwater modelling (Appendix I) indicates that groundwater levels would rise under all areas used for irrigated agriculture but that groundwater pumping would successfully limit the groundwater mounding beneath most of the Project Area. The effectiveness of groundwater pumping for water-level control in the ORIA Stage 1 area has also been investigated and confirmed by the Water and Rivers Commission and described by O'Boy (1997, 1998). Groundwater pumping is also used extensively as a means of groundwater control in the Burdekin River Irrigation Area in Queensland.

In the long term, groundwater pumping would be the primary management tool for controlling rising water levels. Some isolated areas would require the use of field drains to control groundwater levels in the long term.

It is noted that the predicted groundwater levels are based upon average hydrological parameters, and average accession rates (Section 6.4.2 refers). This approach is valid for planning purposes due to the regional response of groundwater systems. However, in reality, the assumed parameters would exhibit a degree of spatial variation, and local variations in the predicted responses would be expected. In extreme cases these variations between observed and predicted response may be significant.

The modelling was used to classify the Project Area into Groundwater Management Zones. Zones where groundwater levels rise to within 5 m of ground surface in the absence of any dewatering system during the fifty-year simulation period are deemed to require groundwater control. Zones where groundwater levels rise to within 1 m of ground surface in the absence of any dewatering system are deemed to be susceptible to waterlogging. The classification system used to define Groundwater Management Zones for the Project is provided in Table 6.2. Zone 1 denotes an area within which no management is required, whilst Zone 5 denotes an area generally unsuitable for long-term irrigation.

The Groundwater Management Zone map developed from the results of the groundwater modelling is presented as Figure 6.2. It is noted that the Project Area includes no lands categorised within either Zone 1 or Zone 5. A more detailed description of predicted changes to groundwater levels beneath the Weaber Plain, the Keep River Plain and the Knox Creek Plain follows. Section 6.5.4 describes the predicted changes to groundwater quality.

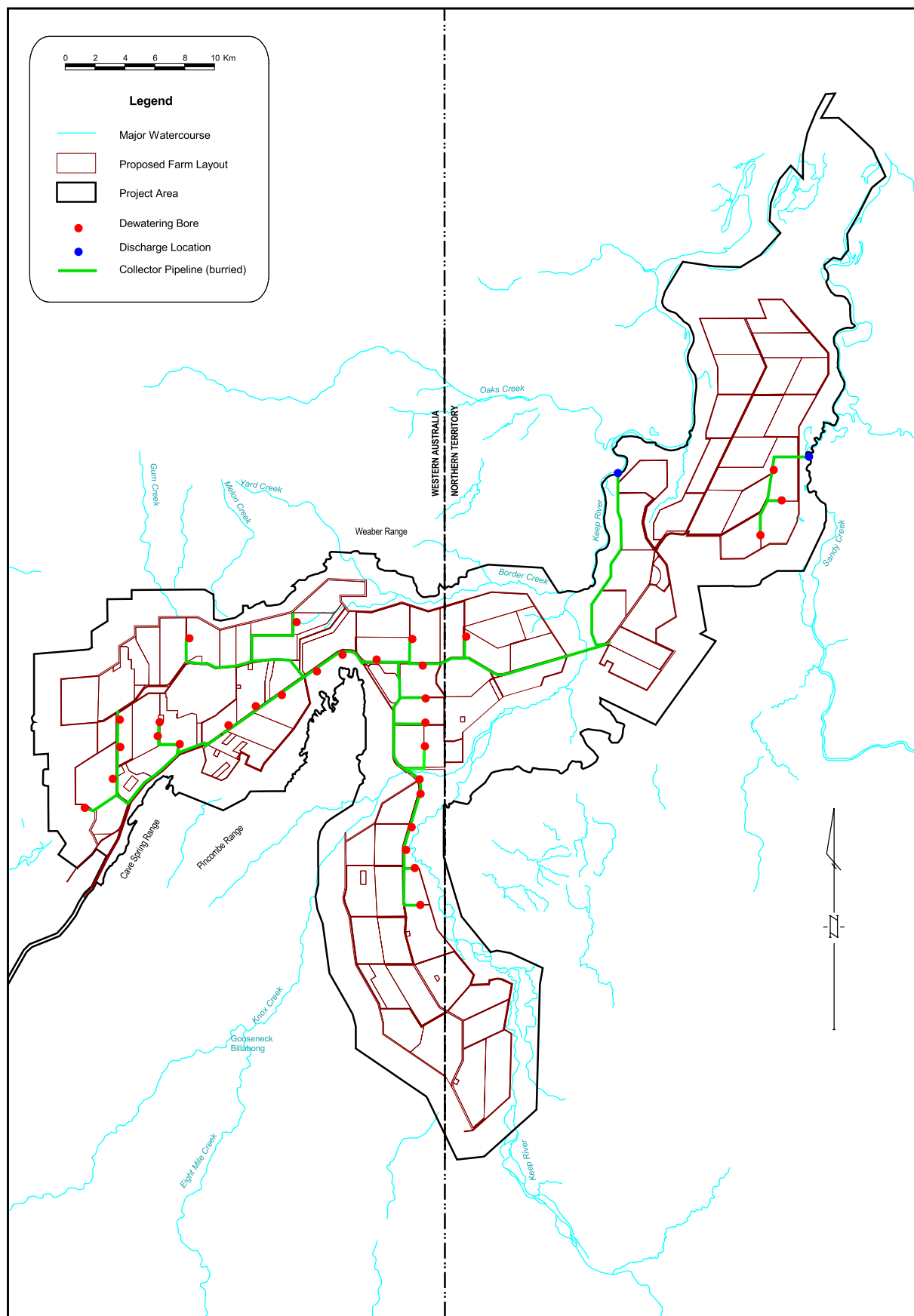


Figure 6.1 Conceptual dewatering bore layout

Table 6.2 Groundwater management classification system

Classification	Description	Management action required
Zone 1—Passive groundwater management	Groundwater readily drains naturally and a relatively deep steady-state water-level (equilibrium condition) would be readily achieved. Groundwater control measures would not be required.	None.
Zone 2—Minor groundwater management	Natural groundwater drainage is not sufficient to prevent rising water-levels but, combined with available groundwater storage, is sufficient to accept the accessions. These areas would remain viable for irrigation for fifty years, without groundwater control.	Monitoring of groundwater level and quality.
Zone 3—Moderate groundwater management	Natural groundwater drainage is not sufficient to prevent rising water-levels. Some areas may have significant groundwater storage capacity or the area may be underlain by permeable units that allow groundwater pumping from bores. These areas would require groundwater control to remain viable for long-term irrigation.	Monitoring of groundwater level and quality; dewatering bores.
Zone 4—Intensive groundwater management	Natural groundwater drainage is poor and water-levels rise significantly under irrigation, leading to possible waterlogging. Groundwater control via dewatering bores would be required for viable long-term irrigation. Field drains may be required in some areas.	Monitoring of groundwater level and quality; dewatering bores; field drains.
Zone 5—Unsuitable for long-term irrigation	Natural groundwater drainage is very poor and initial groundwater levels are high; rapid waterlogging and/or salinisation expected. Groundwater control would not be practical using either bores or field drains. Long-term irrigation would not be viable.	Long-term irrigation avoided.

Weaber Plain

The Weaber Plain falls into Zones 3 and 4, both of which require groundwater control to ensure water-levels are maintained at suitably deep levels.

Predicted accessions from the M2 Channel, and in particular the balancing storage dams, would add significantly to the rate of water-level rise in adjacent areas. Some natural groundwater drainage would occur as throughflow within the palaeochannel, however, the bulk of the accession water would enter groundwater storage (i.e. rising water-table) or be discharged via pumping from bores.

For most of the Weaber Plain, the initial groundwater levels are 10 m and commonly more than 15 m beneath ground level. The length of time taken for the water-table to rise to near ground level would therefore allow for regular review of the response of the groundwater regime to irrigation and for intervention to be timed to suit the observed responses.

The north-western portion of the Weaber Plain area is underlain by rock with low permeability and has an initial shallow water-table (less than 10 m below ground level). The absence of a permeable subsurface unit (on current knowledge) implies that pumping is unlikely to be effective in this area. Agricultural field drains would be required in this area if groundwater mounding approached the surface. A large portion of this area has significant conservation value and would be devoted to conservation, thereby mitigating potential increases in accessions to groundwater and consequential impacts associated with rising groundwater levels in this area (Chapter 10 refers).

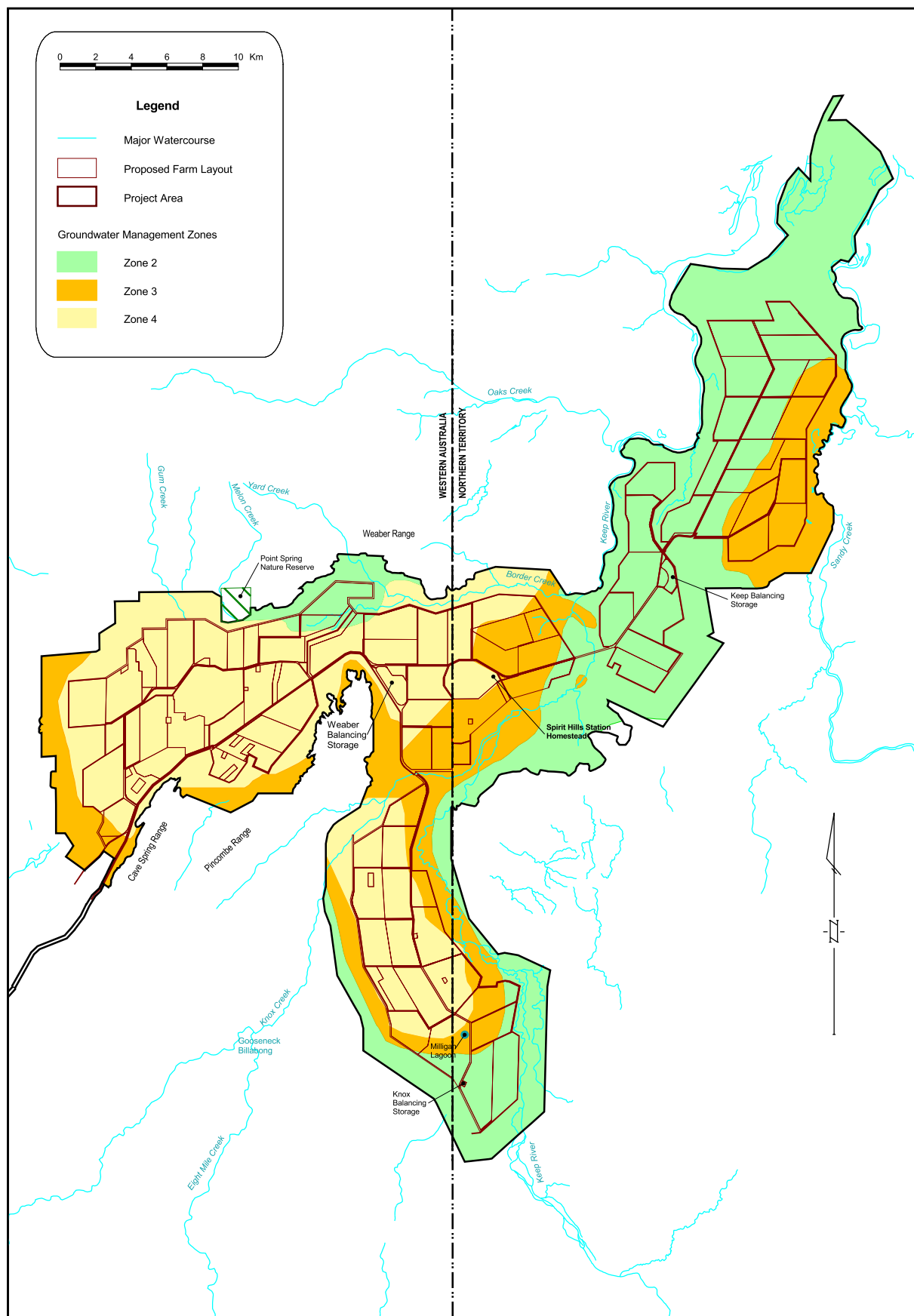


Figure 6.2 Groundwater management zones

As mentioned in Section 6.3.1, the wetland associated with Point Spring is associated with a different system to the alluvial sediments of the Weaber Plain, hence impacts to the wetland are not predicted.

A groundwater mound is predicted to develop to the north of the Weaber balancing storage dam, where the palaeochannel diverts around a Cockatoo Land System inlier within the black-soil plains. It is envisaged that closely spaced dewatering bores and possibly field drains would be sufficient to control the lateral spread of this groundwater mound into adjacent areas.

Keep River Plain

The Keep River Plain has been classified as Groundwater Management Zones 2 and 3.

The lower Keep River Plain is naturally well drained via groundwater throughflow and lateral discharge into the Keep River and Sandy Creek, and the modelling results indicate that it quickly approaches equilibrium conditions when dewatered using bores. The initial water-levels are within 10 m of the surface and in the lower-lying flanking areas within 5 m. Because of the shallow water-table, there may not be a significant response time to observe and plan for water-level rises and therefore production dewatering bores would be installed early in the Project to be available as needed.

The modelling results indicate that the upper Keep River Plain would continue to experience water-level rise throughout the fifty-year simulation period, albeit at rates that would be relatively small. The initial depth to groundwater in the upper Keep River Plain is greater than 10 m and this factor, together with natural drainage and dewatering, should prevent unacceptably shallow water-tables developing over the life of the Project.

Knox Creek Plain

The Knox Creek Plain has been categorised in Groundwater Management Zones 2, 3 and 4. All areas of the Knox Creek Plain proposed for development have initial groundwater levels at depths greater than 10 m and largely at depths below 15 m.

The development area would exclude Milligan Lagoon, a surface expression of a locally perched water-table. Drilling undertaken for the Project has shown that the regional groundwater level is approximately 20 m below the water-level in Milligan Lagoon, confirming the presence of two independent aquifers in this locality. Milligan Lagoon occurs within this shallow perched aquifer, which is hydrologically isolated from the regional aquifer that would be impacted by irrigation.

Current planning for the Project recognises the potential interaction of Milligan Lagoon with the surface hydrology of the surrounding area. The location and extent of hillside drain HD×1 would be reviewed further during detailed design work in order to minimise any impact on this water body.

As with the Weaber Plain and the upper Keep River Plain, the groundwater modelling results indicate that groundwater levels on the Knox Creek plain would rise for the entire fifty-year simulation. However, the significant depth to the existing water-table would provide long lead times before water-levels rise to within 5 m of the surface—approximately twenty years with no dewatering.

The groundwater modelling assumed that dewatering using bores would not be effective in the shallow basement rocks (mostly limestone) that underlie the Western Knox Creek Plain. Based on this assumption, the model results indicate that the western areas of the Knox Creek Plain may experience water-tables within 5 m of the surface after about thirty years and local waterlogging after forty years, even with pumping from the palaeochannel aquifer immediately to the east. It may therefore be necessary to control the groundwater mound beneath the western Knox Creek Plain using field drains. However, further investigations would be undertaken prior to development to ascertain whether this area contains zones of high permeability, as would normally be associated with limestone basement complexes.

Impacts on watercourses

The USGS MODLOW groundwater model was also utilised to predict groundwater discharges to watercourses due to regional rises in groundwater levels. However, the model was not utilised to differentiate between discharges that would be taken up by evapotranspiration by riparian and other vegetation, direct evaporation from soil, and groundwater induced streamflow. The latter would only occur if the discharge rate exceeded the combined evapotranspiration and direct evaporation rates and the water-table reached the watercourse bed level. The predicted maximum rates of groundwater discharges to the non-tidal portions of the regional rivers and creeks are summarised in Table 6.3.

Table 6.3 Predicted maximum groundwater-induced discharges to non-tidal portions of watercourses

Year	Keep River		Knox Creek		Sandy Creek	
	ML/a	mm/a*	ML/a	mm/a*	ML/a	mm/a*
10	7,048	500	0	0	1,118	220
20	8,117	580	0	0	1,134	230
30	8,847	630	25	5	1,168	230
40	9,361	660	61	10	1,205	240
50	9,767	700	96	20	1,236	250

* Discharge rate over affected portion of watercourse, assuming 500 m width.

Table 6.3 also provides an estimate of the discharge rate by area along the potentially affected sections of these watercourses. The 500 m width assumed in these calculations equates to the minimum width of riparian vegetation mapped along these watercourses (Section 7.2.1 refers). It should be noted that the width of riparian vegetation that would remain following development would exceed 1000 m at most locations. Furthermore, the predicted rate of groundwater discharge is lower than the net evaporation rate of 2,100 mm/a for the region (Section 4.1 refers), which implies a low risk of permanent streamflows in the existing ephemeral portions of the watercourses as a result of the proposed development.

The use of the groundwater by vegetation, and direct evaporation from the soil, would result in the concentration of salts. From the information currently available it is not possible to determine with accuracy whether this effect would be detrimental to riparian and other vegetation or whether the salts would be flushed from the soil profile during annual flooding of the watercourses in the wet season. For this reason, health of riparian vegetation and groundwater levels and quality would routinely be monitored as part of the project operations by the EME (Chapter 16 refers). The groundwater pumping strategy would include provision for capture of additional groundwater adjacent to the watercourses if considered necessary.

6.5.4 Predicted changes to groundwater quality

Salinity

The quality of the irrigation water sourced from Lake Kununurra (salinity level of about 160 mg/L TDS) is a major factor in determining the quality of any groundwater accessions. Another factor of importance is the relative contribution of accessions from the cropping areas, which may have elevated salinity levels due to the effects of evapotranspiration, and seepage of irrigation water from infrastructure.

Mass balance calculations based upon the relative accession rates described in this ERMP/draft EIS indicate that the average salinity of all the accessions combined would be about 2,200 mg/L TDS. This calculation assumes that the salts in the irrigation water would behave in a conservative manner, with no chemical reactions or precipitation from solution occurring. In reality, the combined effect of evapotranspiration increasing the concentration of salts and the high soil alkalinity (greater than pH 9 for most of the black soils within the Project Area) would cause the precipitation of carbonates and bicarbonates from the accession water. These salts contribute over half (120 mg/L alkalinity as bicarbonate) of the total salinity of the irrigation water, and hence the assumption that the dissolved salts would behave in a conservative manner could significantly overestimate the salinity of the accession water from the Project Area (although the magnitude of the overestimation cannot be quantified with the available data).

The groundwater of the Weaber Plain is fresh to brackish. In the west the salinity is around 1,000 mg/L TDS (Nixon 1997e). Throughout the southern and central parts of the plain, groundwater salinity ranges from 70 mg/L TDS to 2,600 mg/L TDS. The calculated salinity of the groundwater accessions of about 2,200 mg/L TDS is comparable to, but slightly higher than, the general groundwater salinity beneath the Weaber Plain and therefore no cumulative impacts are expected.

The groundwater salinity beneath the Keep River Plain is more variable than for the other areas, ranging from about 100 mg/L TDS to 51,000 mg/L TDS. It is likely that the higher salinity is influenced mostly by the proximity of the tidal portions of the Keep River and Sandy Creek, which are hydrologically connected to the groundwater regime. The salinity of the accession water would be lower than the salinity of the existing groundwater beneath much of the lower Keep River Plain. Negligible impacts are therefore predicted. In the lower Keep River Plain, it is possible that soil salts may provide a significant contribution, to the net salinity of the accession water, and effectively raise the salinity of the accession water to near that of the existing groundwater.

The groundwater salinity in the Knox Creek Plain ranges from 60 mg/L TDS to 13,000 mg/L TDS, but in general is around 1,000 mg/L TDS (Nixon 1997a). The higher salinity is generally associated with the shale basement complex where downward flushing is inhibited. The accession water salinity would be within the observed range of groundwater salinity and therefore no significant impacts are expected.

Nutrients and chemicals

The black soils typical of the Project Area are known to be highly effective in binding phosphorus, and elevated levels of this nutrient are not anticipated in the groundwaters beneath the Project Area.

Migration of nitrogen to groundwater is generally less affected by soil conditions than phosphorous. The Water and Rivers Commission (O'Boy 1998) measured nitrogen levels (as total nitrate) in groundwaters below the Ivanhoe Plain and the Packsaddle Plain in ORIA Stage 1. The results show total nitrate level (calculated as nitrogen) of approximately 2 mg/L and 1.2 mg/L in groundwater beneath the Ivanhoe Plain and the Packsaddle Plain respectively. These levels are similar to naturally occurring levels in groundwater beneath the Project Area, which are generally below 1–2 mg/L (Section 6.3.2).

It is postulated that the current nitrogen levels in groundwater under ORIA Stage 1 would not be representative of future levels under the Project Area due to the higher rates of accessions to groundwater in ORIA Stage 1 providing additional dilution. For example, the predicted average salinity of groundwater accessions for the Project is about 2,200 mg/L TDS, whereas measured salinity levels in ORIA Stage 1 are 1,200–1,800 mg/L TDS for the Ivanhoe Plain and 430–600 mg/L TDS for the Packsaddle Plain (O'Boy 1998). If the additional dilution in ORIA Stage 1 is taken into account, it would be reasonable to expect that total nitrate levels in groundwater in the Project Area would be in the range of 3.1–5.2 mg/L. Although the predicted levels are about twice the naturally occurring levels, they remain relatively low. For example, the drinking-water guideline value is 10 mg/L (ANZECC 1992).

The observation that black soils are effective in preventing the migration of pesticides from the surface to groundwater, made in other irrigation areas in Australia, has been confirmed by analyses undertaken by the Water and Rivers Commission of groundwater beneath ORIA Stage 1. The analyses involved testing water samples from two bores undergoing long-term pumping tests: one on the Ivanhoe Plain and the other on the Packsaddle Plain. The analyses included a comprehensive range of organochlorine and organophosphate pesticides currently or previously used in the ORIA, at a detection limit of 0.01 µg/L per chemical. The results (O'Boy 1998) showed that no pesticides (organochlorines or organophosphates) were detected in the water samples.

6.5.5 Monitoring programme

Groundwater monitoring for the Project would commence with delineation drilling across the interpreted position of the palaeochannel aquifers in order to define their actual position beneath the irrigation area.

An extensive network of groundwater monitoring bores would also be installed within and adjacent to the irrigation area prior to the commencement of irrigation. This network would include bore transects aligned perpendicular to the Keep River and Sandy Creek to acquire additional data for the better understanding of the river–groundwater interactions, and the establishment of monitoring bores adjacent to Milligan Lagoon.

Groundwater samples would be collected during the delineation drilling to quantify the vertical and horizontal water quality distribution.

Test dewatering bores would be installed and tested to confirm aquifer yields and the response of the aquifers to pumping. The data collected by the above programmes would be used to continually update the groundwater model and to optimise the extent and timing of installation of the groundwater management system.

The quality of groundwater adjacent to watercourses would be monitored. The groundwater pumping strategy would include provision for the capture of additional groundwater adjacent to the watercourses if considered necessary.

7 Existing environment—terrestrial vegetation and flora

This chapter reviews the existing terrestrial vegetation and flora of the region, as well as the conservation significance of vegetation associations and species in the Project Area. The chapter also describes and summarises past surveys and comparative studies of the Project Area and regional vegetation. Other chapters of relevance are Chapter 8, which describes the terrestrial fauna; Chapter 9, which describes the aquatic flora and fauna; and Chapter 10, which describes the proposed conservation strategy for the Project.

7.1 OVERVIEW

7.1.1 The Victoria–Bonaparte Biogeographic Region

The Project Area lies within the Victoria–Bonaparte Biogeographic Region of the Interim Biogeographical Regionalisation for Australia, as developed by the Australian Conservation Agency (Thackway and Cresswell 1995). The region adjoins the lower part of the Joseph Bonaparte Gulf and is about 73,000 km² in extent. It exhibits a diversity of landforms and vegetation types, including red earth and black-soil (‘cracking-clay’) plains, plateaux, ranges of sandstone, open savanna and tall grassland.

The Kimberley region has generally proved problematic for land and industrial development because of its isolation, vast rugged landscape and climate. As a consequence, formal biological studies to date have been limited.

Scientific knowledge of the vegetation and fauna of cracking-clay environments in the Victoria–Bonaparte Biogeographic Region is limited, and there is no one single or comprehensive account of the biota of these habitats and their biogeography. The majority of research to date on cracking-clay environments has concentrated on the northern floodplains and, in particular, the Alligator River region of the Northern Territory. In 1999, the Parks and Wildlife Commission of the Northern Territory (PWCNT) received a grant to undertake biological surveys of the cracking-clay systems throughout the Northern Territory. The current PWCNT research will extend the biological knowledge of the region.

7.1.2 Biological surveys in and adjacent to the Project Area

Published biological surveys of varying relevance to the Project Area are summarised in Table 7.1. Many of the studies do not include work within the Project Area, and are either specific to small areas or broad-scale (regional) in nature (e.g. Beard 1979; Stewart et al. 1970; Wilson et al. 1990).

Table 7.1 Published biological information* for the region

Reference	Description
Gardner (1923) and Perry (1956)	Preliminary descriptions of the vegetation of the Kimberley region.
Stewart et al. (1970)	Vegetation survey of the Northern Territory.
Miles and Burbidge (1975)	Biological surveys in the Prince Regent River Nature Reserve.
Kabay and Burbidge (1977)	Biological surveys in the Drysdale River National Park.
Aldrick and Moody (1977); Dixon (1996)	Soils of the Weaber and Keep River plains, including some details of vegetation within the Project Area.
Beard (1979)	An account of previous botanical exploration in the Kimberley region and an outline of broad-scale vegetation types.
Henshall and Mitchell (1979)	Vegetation survey of the Keep River area.
Gowland and Sonnemann (1980)	Reptile and amphibian survey for the north-east Kimberley region.
Gowland and Brennan (1980); Gowland (1980)	Bird and mammal survey for the ORIA.
Western Australian Museum (1981)	Biological survey of Mitchell Plateau and Admiralty Gulf.
Dames & Moore (1982)	Biological survey for the Argyle Diamond Project.
McKean (1986)	Avifauna of the Keep River National Park.
Forbes and Kenneally (1986)	Plant life in the Purnululu National Park and Osmond Range.
Tidemann et al. (1987)	Unpublished ecological survey of Spirit Hills Station, which focused on the upland sandstone area.
Wilson et al. (1990)	Vegetation mapping of all the Northern Territory.
Petheram and Kok (1991); Wheeler et al. (1992)	Monographs of the flora of the Kimberley region.
McKenzie et al. (1991)	A wide-scale survey of Kimberley rainforest areas.
Department of Conservation and Land Management (1992)	Biological surveys in the Purnululu National Park.
Connors, Oliver and Woinarski (1996)	Biological data for the Victoria–Bonaparte Biogeographic Region in the Northern Territory portion.
Ecologia (1997a)	Terrestrial Biological Assessment of the Project Area.
Ecologia (1997b)	ORIA Stage Two Riverside Development Area Terrestrial Biological Assessment.
Connell Wagner Pty Ltd (1997)	EIS and EMP for the Bradshaw Field Training Area, Northern Territory.
Brocklehurst et al. (1998)	Botanical survey of Auvergne Station and sections of Spirit Hill Station.
Department of Conservation and Land Management (1998)	Draft management plan for the lower Ord River Ramsar site.
Larson (1999)	Survey of aquatic fauna in the Keep River, Border Creek, Knox Creek and lagoons.
Kinhill Pty Ltd (1999) (Appendix J)	Additional survey of the flora and fauna of the Project Area.

* Includes fauna surveys that contain some information on vegetation and flora.

Detailed terrestrial vegetation and flora surveys within the Project Area have recently been conducted for the Project by Ecologia (1997a) and by Kinhill in 1999 (see Appendix J). Prior to these comprehensive surveys, no detailed flora surveys had been conducted on the black-soil plains within the Project Area.

The Ecologia surveys were commissioned by the Department of Resources Development to provide baseline data on the terrestrial biology of the Project Area for use in an unpublished

Public Environmental Review. These surveys were undertaken in the 1996 dry season and 1996–97 wet season by a team of thirteen botanists and zoologists. A total of eighty-six sites was surveyed in the dry season and forty-five sites in the wet season. Nineteen of the wet-season sites were new sites and twenty-six were dry-season sites that were re-sampled, making a total of 105 different sites that were sampled during the surveys.

Brocklehurst et al. (1998) undertook a survey of Auvergne Station and a section of the Spirit Hills Station in the Northern Territory. This area is approximately 100 km east of the Project Area and, like the Project Area, includes extensive cracking clays typical of the Ivanhoe land system. The survey was commissioned by the Northern Territory Government to compare the vegetation in these areas with the vegetation recorded in the Ecologia surveys of the Project Area (see Section 7.2.2).

The Kinhill surveys were commissioned by Wesfarmers–Marubeni and the Water Corporation to supplement the data from the Ecologia (1997a) surveys and enable the preparation of a vegetation map of the Project Area (Section 7.2.1). Two surveys were undertaken, in May and June 1999. The rock outcrops, watercourses and lagoons were not resurveyed by Kinhill. The data obtained by Ecologia were used to prepare the vegetation map in these portions of the Project Area.

AGWEST has undertaken surveys in the East Kimberley as part of the Western Australian Rangeland Monitoring System (WARMS). These unpublished surveys form part of a long-term monitoring strategy, which monitored sites established on pastoral leases that include all ten of the land systems identified in the Ord–Victoria area by Stewart et al. (1970). The WARMS data are compared with those for the Project Area in Section 7.2.3.

During 1999, the Parks and Wildlife Commission of the Northern Territory commenced a biological survey of the cracking-clay systems across the Victoria River Downs and the Barkly District (G. Leach, Biodiversity Unit, Parks and Wildlife Commission of the Northern Territory, pers. comm., February 1999). The sites selected include thirty-five from Spirit Hills/Legune/Keep River area, and seventy-nine on Bradshaw and Auvergne stations (A. Fischer, Parks and Wildlife Commission of the Northern Territory, pers. comm., December 1999). The data available from this research was not available at the time of publication of this ERMP/draft EIS.

The cracking-clay soils earmarked for the proposed development have been well surveyed, although the surrounding rocky areas and the riverine vegetation have not been investigated in the same detail.

7.2 VEGETATION IN AND ADJACENT TO THE PROJECT AREA

The Western Australian portion of the Project Area lies within the eastern section of the Gardner Botanical District and was described by Beard (1979) as ‘grassland with sparse bauhinia (*Bauhinia cunninghamii*) and coolibah (*Eucalyptus microtheca*) on cracking clay soil’. In 1990 Beard further expanded the description of the black-soil plains of the Ivanhoe Land System, describing it as treeless, or with low trees 3–6 m high, including coolibah (*Eucalyptus microtheca*), bauhinia (*Bauhinia cunninghamii*), corky bark wattle (*Acacia ditricha*), *Terminalia* spp. and guttapercha tree (*Excoecaria parvifolia*). Shrubs include mimosa bush (*Acacia farnesiana*) and sparse conkerberry (*Carissa lanceolata*). The typical ground layer is a community of tall, perennial grasses reaching 2 m and more in height. Common grass species include blue grass (*Dichanthium tenuicolum*, *Dichanthium*

fecundum), plume sorghum (*Sorghum plumosum*), *Sorghum timorense*, silky browntop (*Eulalia fulva*), canegrass (*Ophiuros exaltatus*) and bull mitchell grass (*Astrebla squarrosa*).

The portion of the Project Area within the Northern Territory was mapped by Wilson et al. (1990) and described as golden beard grass (*Chrysopogon fallax*) and blue grass (*Dichanthium fecundum*) grassland.

7.2.1 Vegetation mapping of the Project Area

A vegetation map of the Project Area was considered essential to assist in the planning and selection of conservation areas.

The data from the Kinhill and Ecologia surveys, and an interpretation of aerial photography, were used to produce the vegetation map of the Project Area shown in Figures 7.1, 7.2 and 7.3. The vegetation map is complex; however, the vegetation variation depicted is distinctive and consistent in the field.

Based on the information from Ecologia (1997a) and Kinhill Pty Ltd (1999), a total of seventy-two vegetation communities within seventeen major groups is recognised (Appendix J). Examples of some vegetation communities in the Project Area are shown in Figure 7.4.

Connors et al. (1996) listed twenty-eight fine scale vegetation units for the Victoria–Bonaparte Biogeographic Region. Nine of these coincide with twenty-three of the seventy-two vegetation communities described for the Project Area as shown in Table 7.2.

Table 7.2 Fine Scale Vegetation Units represented in the Project Area (Connors et al. 1996)

Description of Fine Scale Vegetation Units	Vegetation Unit Number*	Project Area vegetation communities†
<i>Eucalyptus miniata</i> , <i>Eu. tetradonta</i> open forest with <i>Sorghum</i> grassland understorey	4	Min2
<i>Eu. microtheca</i> , <i>Excoecaria parvifolia</i> low woodland with <i>Chrysopogon fallax</i> , <i>Dichanthium</i> grassland understorey	24	Em1, Em2, Em3, Em4, Em5, Em6, Em7, Em8
<i>Bauhinia cunninghamii</i> mixed species low open woodland with <i>Sehima nervosum</i> , <i>Chrysopogon fallax</i> open grassland understorey	46	Bc1, Bc2, Bc3
<i>Melaleuca minutifolia</i> low woodland with <i>Sorghum</i> grassland understorey	50	Me4
<i>Melaleuca viridiflora</i> , <i>Eucalyptus</i> low open woodland with <i>Chrysopogon fallax</i> grassland understorey	51	Cb6, Me2
Mixed closed-grassland/sedgeland (Seasonal floodplain)	54	G6, G7
<i>Astrebla</i> , mixed species grassland with scattered trees and shrubs	97	Em6
<i>Chrysopogon fallax</i> , <i>Dichanthium fecundum</i> grassland	98	G1, G2, G3, G4
<i>Xerochloa</i> grassland	104	G5

* Source: Connors et al. (1996).

† Source: Kinhill Pty Ltd (see Appendix J).

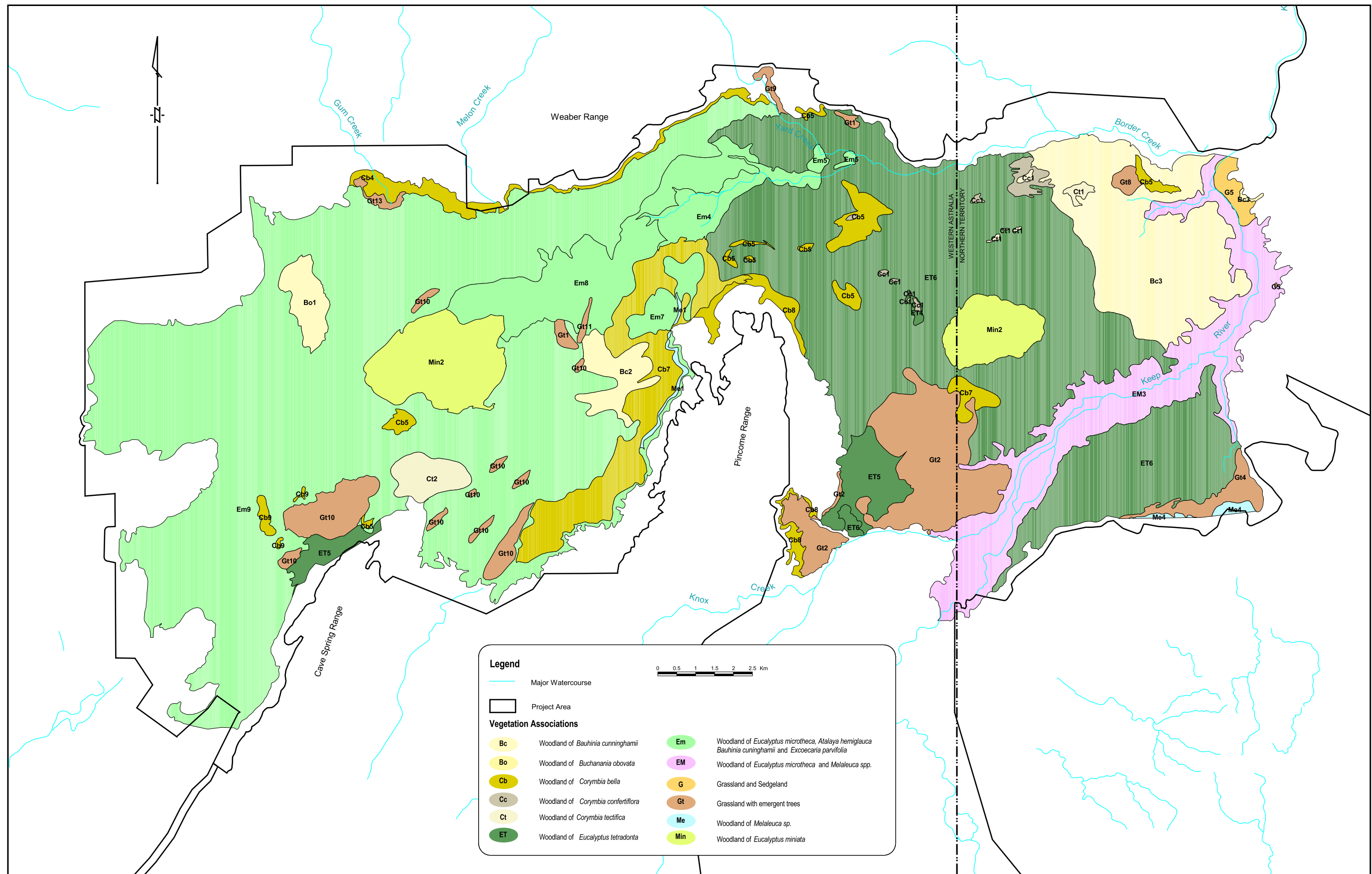


Figure 7.1 Vegetation associations of the Weaber Plain

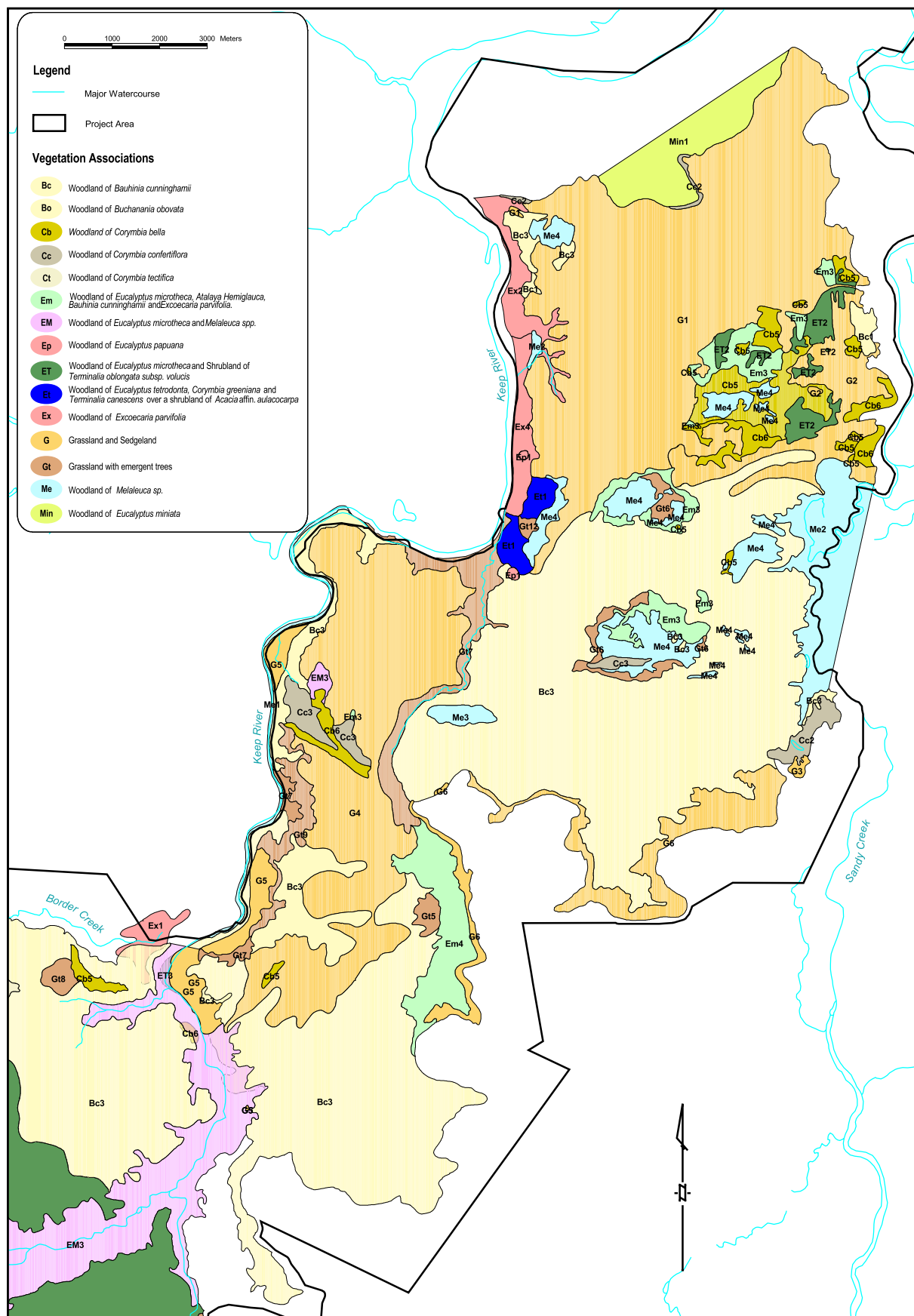


Figure 7.2 Vegetation associations of the Keep River Plain

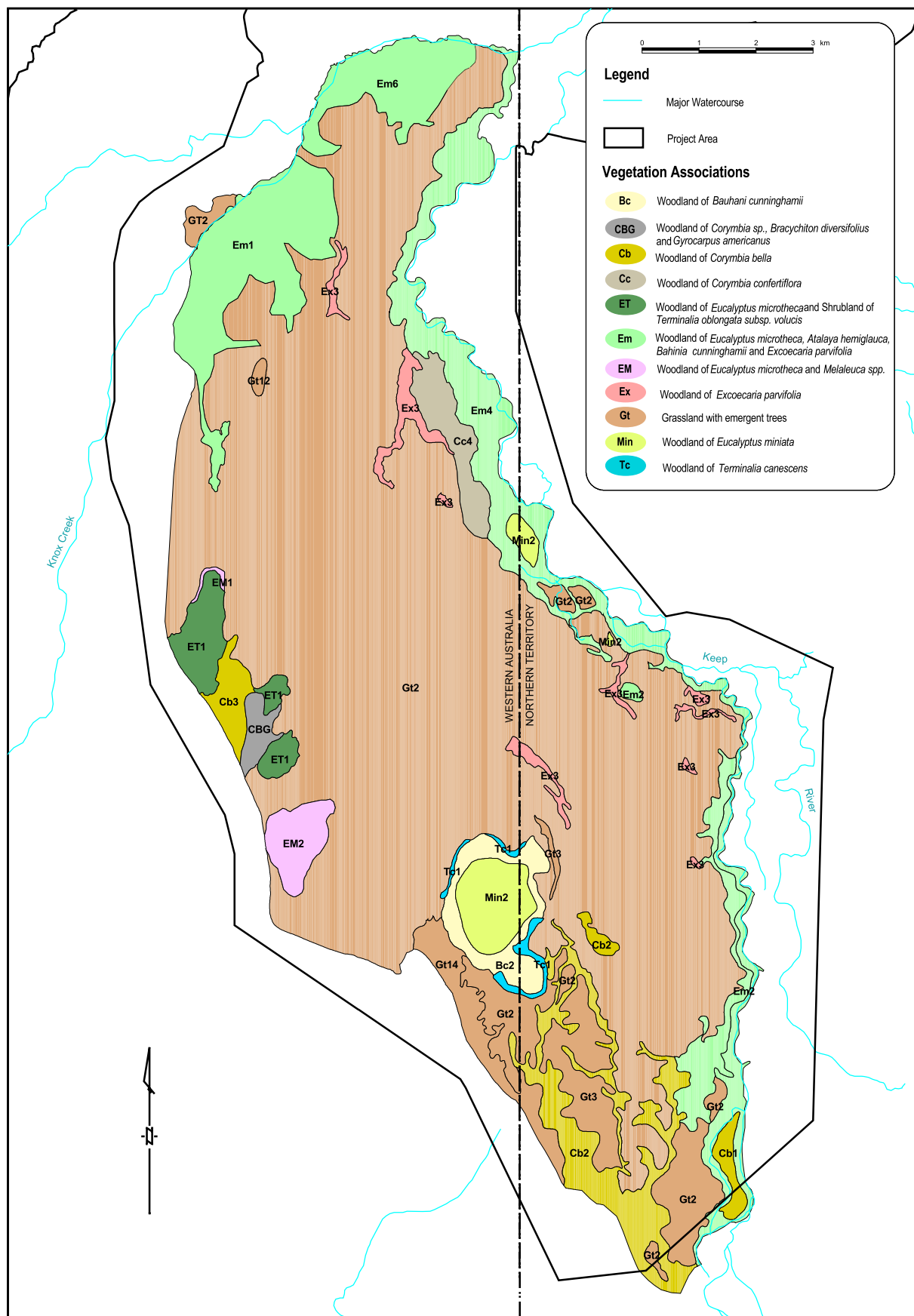


Figure 7.4 Selected vegetation communities of the Project Area



Ex3 Woodland of *Excoecaria parvifolia* with scattered *Eucalyptus microtheca* over a low grassland dominated by *Sehima nervosum* and *Cyperus viscidulus*. Occurs on the Knox Creek Plain. Soil Unit 1e.



Ex 2 Woodland of *Excoecaria parvifolia* over an open to dense grassland dominated by *Ophiuros exaltatus*, *Iseilema fragile* or *Heteropogon contortus*. Occurs on the Keep River Plain in Soil Unit 1.



Cb5 Open Woodland of *Terminalia platyphylla*, and *Corymbia bella* over an open woodland of *Bauhinia cunninghamii* and *Terminalia oblongata* subsp. *volucris* and scattered *Acacia ditricha* over a dense annual and tussock grassland of *Themeda triandra*, *Heteropogon contortus*, *Aristida latifolia*, *Ophiuros exaltatus* and *Sorghum timorense*. Occurs on the Weaber and Lower Keep River Plain. Soil Units 4a, 4b, 4c.



G1 Dense Grassland mosaic dominated by *Heteropogon contortus*, *Iseilema fragile*, *Themeda triandra*, *Chrysopogon fallax* or *Sorghum timorense*. Occurs on the northern Keep River Plain. Soil Unit 1.



Cc1 Open Woodland of *Corymbia confertiflora*, *Planchonia careya* and *Terminalia latipes* var. *latipes* over moderately dense *Bauhinia cunninghamii* and a very open tussock grassland of *Heteropogon contortus*, *Themeda triandra* and *Sorghum plumosum*. Occurs on the Weaber Plain. Soil Unit 2b.

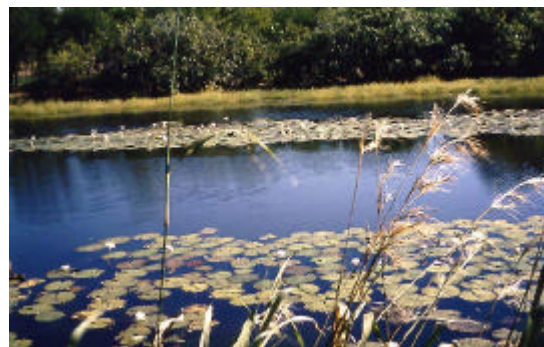


EM7 Open Woodland of *Eucalyptus microtheca* and *Acacia ditricha* over a tall grassland dominated by *Oryza australiensis* and *Sorghum timorense* over *Panicum decompositum*. Occurs on the Weaber Plain. Soil Unit 1.

Figure 7.4 Selected vegetation communities of the Project Area (continued)



ET6 Open Low Woodland of *Excoecaria parvifolia*, *Bauhinia cunninghamii* and *Eucalyptus microtheca* over a Shrubland of *Terminalia oblongata* subsp. *volucris* and a grassland of *Panicum decompositum*, *Iseilema vaginiflorum* and *Sorghum timorense*. Occurs on the Weaber Plain. Soil Unit 1.



G7 Open Sedgeland dominated by *Eleocharis dulcis* and *Schoenoplectus praelongatus* with emergent *Excoecaria parvifolia* and *Barringtonia acutangula* on the edge of Milligans Lagoon. Occurs on the Knox Creek Plain. Soil Unit 1.



Me 4 Woodland of *Melaleuca minutifolia*, *Melaleuca viridiflora*, *Excoecaria parvifolia* and *Cochlospermum fraseri* over a grassland of *Themeda triandra*. Occurs on the Keep River Plain. Soil Units 2a, 2a/3a, 3a/4a.



Em3. Dense vegetation surrounding the lagoon on the Keep River at Legune Crossing. Soil Unit 7.



GT2 Dense grassland of *Iseilema vaginiflorum*, *Aristida latifolia*, *Sorghum timorense*, *Themeda triandra* with emergent *Eucalyptus microtheca*, *Excoecaria parvifolia*, *Atalaya hemiglauc*a and *Bauhinia cunninghamii*. Occurs on the Knox Creek Plain. Soil Unit 1.



Bc1 Low Woodland of *Bauhinia cunninghamii* over tussock and annual grassland of *Iseilema* sp., *Panicum decompositum*, *Sehima nervosum*, *Aristida latifolia*, *Cyperus bifax*, *Sehima nervosum*, *Chrysopogon fallax* and *Sorghum timorense*. Occurs on the Weaber and Keep River Plains. Soil Unit 1.

The Keep River Plain has extensive areas of grassland with no, or only a few, scattered trees, which include coolibah (*Eu. microtheca*), *Corymbia bella*, guttapercha tree (*Excoecaria parvifolia*), corky bark wattle (*Acacia ditricha*) and bauhinia (*Bauhinia cunninghamii*). The vegetation of the Knox Creek Plain is predominantly grassland with emergent to dense low trees dominated by coolibah (*Eu. microtheca*), guttapercha tree (*Excoecaria parvifolia*), *Atalaya hemiglauca* and bauhinia (*Bauhinia cunninghamii*). The Weaber Plain is similar to the Knox Creek Plain, namely, a grassland with emergent trees dominated by coolibah (*Eu. microtheca*), guttapercha tree (*Excoecaria parvifolia*) and *Terminalia obovata* subsp. *volucris*. However, sections of the Weaber Plain retain water for longer periods and have grassland species associated with wetter areas (e.g. wild rice [*Oryza australiensis*] and canegrass [*Ophiuros exaltatus*]).

Ecologia (1999) provides an analysis of the floristic data from the Project Area that separates the sites into two broad groups. The first group is the black-soil plains of the Cununurra clay (normal phase) soils, associated cracking clays in depressions and Aquitaine soils. The second group includes sites on a miscellaneous array of soils and substrate types including red soil, sandy or stony substrates or upland areas such as the Cockatoo Land System, and riverbanks.

The Weaber Plain is well represented by Cununurra clay (normal phase) soils and Aquitaine soils; the Keep River Plain by Cununurra clay (normal phase) soils, and the periphery of the plain by Aquitaine soils; and the Knox Creek Plain by Cununurra leached phase soils. These differences in soil types result in a differing degree of representation of vegetation community types and floristics on each of the three plains.

The differentiation of the vegetation communities in relation to soil units is shown in Table 7.3. The seventeen major vegetation groups are listed in the legend on the maps (e.g. Me, ET, Gt), and the description for each vegetation community (e.g. Me4, ET5, Gt10) is given in Appendix J. Only the vegetation groups occurring on the individual maps are listed in the relevant legend.

Thirty-eight different soil units were sampled by Ecologia (1997a) and Kinhill Pty Ltd (1999) (Appendix J refers). Soil Unit 1 (a cracking clay) recorded the greatest diversity of vegetation communities, with four communities recorded for the Keep River Plain, six for the Knox Creek Plain and eight for the Weaber Plain. Some of the variations in these vegetation communities are subtle, while others are more obvious, such as the change from a tree layer dominated by *Eucalyptus microtheca* with grey bark to *Corymbia bella* with a white bark.

Some vegetation communities occur in several soil units but these units are usually adjoining and often small in size. When the structure of the soils varies considerably (e.g. adjacent areas of cracking clay and sand), the change in vegetation is marked. However, in adjacent areas of different clay soils the vegetation generally does not exhibit a significant change.

7.2.2 Comparison of the Project Area with portions of Auvergne and Spirit Hills stations

Auvergne and Spirit Hills stations include the major extent of the Ivanhoe Land System in the Northern Territory (Figure 4.2). A study (Brocklehurst et al. 1998) was commissioned by the Northern Territory Government to compare the vegetation of these black-soil plain areas with that of the Project Area and, in particular, to 'consider whether the plant species diversity and the floristic communities present in the Project Area are well represented in the Auvergne region'.

Table 7.3 Vegetation communities and associated soil units within the Project Area

Soil		Vegetation community*		
Soil Unit	Description	Weaber Plain	Keep River Plain	Knox Creek Plain
1	Cracking clay	Gt2, Gt8, Em6, Em7, ET6, Cb7, Bc1, Ex1	G1, Gt1, Ex2, Cb7 Bc1, Bc3, G3	G7, GT3, Em1, EM1, Bc2
1c	Brownish cracking clay	Em6		
1e	Grey and brown cracking clay			Ex3
1g	Grey cracking clay			Em2
2a	Red-brown earths	Ct1	Cc3	
2b	Red-brown earths, sandy topsoils	Cc1	GT12	
2c	Red earths, sandy topsoils	Ct1		
2a/3a	Complex of 2a/3a		Me4	
3a	Red-brown earths		G2	
3c	Red-brown earths			ET2
3a/4a	Complex of 3a/4a		Me4	
4a	Cracking clays in large depressions	Cb5	GT6, Cb5	
4b	Cracking clays in medium depressions	Em3, Cb5	Em3, Cb5	
4c	Brownish cracking clays	Cb5	Cb5	
4d	Cracking clays with hydromorphic attributes	ET4	Cc2	
5c/4d	Complex 4d with included stones or rocks	G6		
5a	Cracking clays with hydromorphic attributes	Gt4m, GT9, Em4, Em9	ET3	Em4
5b	Cracking clays with hydromorphic attributes	Gt5, ET5, EM8		
5c	Cracking clays with hydromorphic attributes	GT13	G4	
5bt	Cracking clays with hydromorphic attributes	ET5		
5e	Grey cracking clays		ET1, Cb3	ET1
6	Small steep hills	Gt10		
6e				CBG
7	Rivers/streams		Ep1, Ex4, Me3	Cb1
7a	Rivers and major creeks	EM3	G5, GT7, Cb6, Me2	
7a/b	Complex of 7a/7b			Cb1
7b	Cracking clays, severe erosion	Em5		
7f	Remnant levees of prior streams			Cb2
8	Undifferentiated complex of 8a/8b	Cb8		
8a	Complex peripheral zone to sand and laterite			Cc4, Me1
8b	Complex between 8a and sand	Cb4		
9c	Brownish cracking clays	Gt11, Cb9		
11	Colluvial outwash slopes			Gt14, Em2
Rock	Cockatoo		Min1, Et1	Min2
Rock	Dolomite	Bo1		
Rock	Sandstone			Tc1

* Refer to Appendix J for description of communities.

A total of 226 20 × 20 m quadrats was assessed by the survey over seventeen days during March and April 1998. The survey was undertaken on areas of black soil only. The sandstone areas (the Cockatoo Land System) were not surveyed, but the basal area of canopy cover and the plant species present were recorded. A total of thirty-seven vegetation associations in seven main groupings was recorded, but no interpretive mapping was undertaken. As a consequence, the extent of each vegetation association is unknown.

The Auvergne region appears to have a greater variation of vegetation and soil regimes than the Project Area. At a descriptive level, there is a similarity between many of the vegetation associations of the Auvergne region and those of the Project Area; however, the degree of this similarity was unable to be reliably quantified because of the different survey methodology used by Ecologia (1997a) and Brocklehurst et al. (1998).

Ecologia (1999) (Appendix K) compared the vegetation groups in the Auvergne region using Project Area data and noted that six broad associations are present (Table 7.4). Seven of the seventeen vegetation associations identified by Ecologia in the Project Area are not represented in the Auvergne region. Of these, six are associated with non-clay soils that were not sampled by Brocklehurst et al. (1998).

Brocklehurst et al. (1998) considered that Group 1 and Group 5 (cracking clay soils) are most likely representative of the same floristic community and that it was mainly the season when sampled that distinguishes the two groups. Group 1 mainly consists of wet-season sites, and Group 5 predominantly of dry-season sites. Group 1 records herbs and sedges as the dominant understorey species and Group 5 records grasses. Group 3 includes saline sites that are poorly represented in both the Project Area and the Auvergne region. Group 6 includes wetland and riverine sites and their margins.

Compared with the Auvergne region, the Project Area has a predominance of *Sorghum timorensense*, *Acacia ditricha* and *Themeda triandra*, and a scarcity of *Sorghum bulbosum*. The Project Area also has a greater diversity and possibly a higher biomass of plant species than the Auvergne region, but the same dominant species are present in each region.

Table 7.4 Broad vegetation groups of the Project Area and the Auvergne region

Group	Number of sites in Project Area	Number of sites in Auvergne region	Project Area	
			Landforms and soils	Vegetation
1	28	9	Cracking clays	Characterised by sedge and herb understorey.
2	25	79	Red-browns; hills, CcLS; peripheral	<i>Heteropogon contortus</i> , <i>Cayratia trifolia</i> , <i>Corymbia confertiflora</i> , <i>Grewia retusifolia</i> .
3	3	2	Rivers, creeks; inundated; saline	<i>Xerochloa</i> sp., <i>Trianthema</i> sp., <i>Sesbania cannabina</i> , <i>Panicum decompositum</i> , <i>Avicennia</i> sp., <i>Halosarcia</i> sp. etc.
4	8	11	Red-browns; CcLS; peripheral	<i>Acacia hemiglauca</i> , <i>Drosera ordensis</i> , <i>Senna artemisioides</i> .
5	56	87	Cracking clays	<i>Chrysopogon fallax</i> , <i>Bauhinia cunninghamii</i> , <i>Panicum decompositum</i> , <i>Aristida latifolia</i> , <i>Themeda</i> sp., <i>Ophiuros</i> sp.
6	10	19	Creeks, wetland margins	<i>Excoecaria parvifolia</i> , <i>Eucalyptus microtheca</i> .
Total	130	224		

Source: Ecologia 1999.

Note: CcLS = Cockatoo Land System.

Due to the larger number of soil types represented, a greater number of vegetation associations were recorded at Auvergne and Spirit Hills stations than for the Project Area. Differences in sampling methodology (20 × 20 m quadrats by Brocklehurst et al. [1998] and 100 × 100 m quadrats by Ecologia [1997a]) and seasonal differences limit the validity of comparisons of data. Only the presence or absence of species is compared by Brocklehurst et al. (1998) although the differences in the two sampling areas (400 m² and 10,000 m²) reduces the probability of recording a species at one site compared with the other. The Auvergne survey sampled 226 sites making a total of 90,400 m² of sampling area and the Project Area had 133 sites sampled making a total of 1,330,000 m² of sampling area. On sampling area alone, it would be expected that the number of species recorded from the Project Area (550) would be greater than from Auvergne (458). Of the combined list of species from the two surveys, 38% were recorded only from the Project Area, 26% only from the Auvergne region and 36% were common to both surveys. Despite the limitations mentioned earlier, the analysis indicates a relatively high species richness in the Project Area.

7.2.3 Comparison of the Project Area with other areas

Ord Riverside Developments

Ecologia (1997b) was also commissioned by the Department of Resources Development to undertake a survey of the Ord Riverside Developments. These areas have been identified as part of ORIA Stage Two (i.e. suitable for horticultural development) and include Mantinea Flats, the Carlton Plain and the Ord River West Bank area (Figure 1.1). A comparison of the results of the Ecologia surveys of the Project Area (Ecologia Environmental Consultants 1997a) and the Riverside Developments (Ecologia 1997b) is provided in Ecologia (1999). Data analysis clearly separated the Project Area sites from the Riverside Development sites. While there is a significant overlap between the floristic composition of sites from the two areas, there is little representation of Soil Unit 1 (cracking clays) and Soil Unit 5 (cracking clays) in the Riverside Developments; cracking-clay sites predominate in the Project Area.

WARMS

The monitoring method for the WARMS records the presence of perennial species within 100 quadrats (70 × 70 cm) at each site.

Data were provided for thirty-seven WARMS sites within ten land systems identified by Stewart et al. (1970):

- Antrim—five sites
- Inverway—fifteen sites
- Argyle—three sites
- Ivanhoe—one site
- Cowendyne—one site
- Pinkerton—one site
- Frayne—three sites

- Wave Hill—six sites
- Gordon—one site
- Willeroo—one site.

The soils of these land systems are predominantly grey and brown cracking clays of the Cununurra, Argyle and Barkly soil groups (Stewart et al. 1970). Statistical analysis of the data in Ecologia (1999) indicated that the floristic composition of the Ivanhoe Land System (one site only) is distinct from all other WARMS sites and that it can be grouped with sites from the Project Area. However, monitoring of more Ivanhoe Land System sites would be required to confirm whether these results are indicative of a general trend or are restricted to the one Ivanhoe site sampled.

7.2.4 Conservation significance of the vegetation associations

The major vegetation associations of particular conservation significance within the Gardner Botanical District according to Beard (1990) are vine thickets and rainforest. An area along the middle reaches of the Keep River was recorded by Ecologia (1997a) as being a vine thicket, although it was considered degraded due to the long history of pastoral activity as cattle have a tendency to congregate in riverine areas for shelter and water. Several stretches of dense riverine vegetation, especially in the upper reaches of the Keep River within the Project Area, were located by Kinhill Pty Ltd (1999). These areas have the density of a vine thicket, are regarded as ‘vine thickets’ in this area, and are considered to be of conservation significance.

Ecologia (1997a) identified three other vegetation units that have conservation significance:

- Wild rice (*Oryza australiensis*) grasslands, usually with an open overstorey of guttapercha tree (*Excoecaria parvifolia*). The wild rice (*Oryza australiensis*) grasslands were described as rare, and confined to black-soil plains in northern Western Australia and the Northern Territory. The most extensive herb/grasslands of wild rice (*Oryza australiensis*) and *Diplachne parviflora* known in Western Australia dominate the wetland grassland at Parry Lagoon Nature Reserve (Department of Conservation and Land Management 1998). Wild rice has also been recorded as occurring in a number of scattered localities in the Kimberley region as well as in the Project Area. In the Northern Territory, wild rice is found from the Keep River through to eastern Arnhem Land. Three sites (WP1, WP9, WP19) of wild rice (*Oryza australiensis*) are located on the Weaber Plain (Ecologia Environmental Consultants 1997a);
- cork bark wattle (*Acacia ditricha*), bauhinia (*Bauhinia cunninghamii*) low open woodland over fantail grass (*Chrysopogon fallax*) tussock grassland and *Sorghum timorense* annual grassland. Fantail grass (*Chrysopogon fallax*) occurs in a similar habitat to that of wild rice (*Oryza australiensis*), particularly in areas subject to inundation for long periods. This vegetation is widespread throughout the eastern section of the Weaber Plain and dominates the southern section of the Keep River Plain;
- *Echinochloa kimberleyensis*. This was recorded during the wet season from seasonal wetlands on the Knox Creek Plain and Weaber Plain where *Echinochloa kimberleyensis* occurs with wild rice (*Oryza australiensis*) and fantail grass (*Chrysopogon fallax*) in small, scattered populations. The Western Australian Herbarium database records this

plant at Milligan Lagoon (on the Knox Creek Plain), in an area proposed for conservation (see Chapter 10), and in the Keep River National Park.

Connors et al. (1996) identified two fine scale vegetation communities that occur in the Project Area and that are currently unreserved or poorly reserved in the Northern Territory section of the Victoria–Bonaparte Biogeographic Region, namely:

- *Melaleuca minutifolia* low woodland with a *Sorghum* spp. grassland understorey
- *Xerochloa* spp. grassland.

Xerochloa spp. grassland was recorded in the northern section of the Keep River Plain within an area proposed for conservation (Chapter 10). This grassland is common on the mudflats outside the Project Area. *Melaleuca minutifolia* low woodland, typically associated with kangaroo grass (*Themeda triandra*), occurs in Soil Units 2a, 3a or 4a and while some of these areas are proposed for development, large areas would be specifically conserved in the Project Area (Chapter 10).

Mangrove communities are also recommended for preservation (Burbidge et al. 1991). Wightman (1989) indicates that a number of species of mangrove occur along the lower Keep River: white mangrove (*Avicennia marina*), ribbed-fruited orange mangrove (*Bruguiera exaristata*), yellow mangrove (*Ceriops tagal* var. *australis*), red mangrove (*Rhizophora stylosa*) and cedar mangrove (*Xylocarpus moluccensis*). However, only seedlings of white mangrove (*Avicennia marina*) were located by the Kinhill Pty Ltd (1999) surveys along the Keep River within the Project Area. The dense mangrove stands recorded by Wightman (1989) are downstream of the Project Area and near the river mouth. No mangrove plants were recorded along Sandy Creek within the Project Area (Ecologia 1997a).

7.3 FLORA OF THE PROJECT AREA

Based on data provided by the Western Australian Herbarium and the Parks and Wildlife Commission of the Northern Territory, 307 taxa of plants from eighty families were previously recorded within the Ord River area (Ecologia Environmental Consultants 1997a). The most numerous families are Poaceae (grasses—forty-nine taxa), Myrtaceae (eucalypts and paperbarks—twenty-nine taxa), Cyperaceae (sedges and rushes—twenty-three taxa), Mimosaceae (wattles—seventeen taxa), Asteraceae (daisies—thirteen taxa), Papilionaceae (peas—ten taxa) and Combretaceae (*Terminalia* spp.—ten taxa).

The Ecologia survey recorded 682 taxa from eighty-seven families, twenty-six of which were represented by a single taxon. Two hundred and seventy-six genera were recorded, with 138 of these represented by a single taxon. An additional 40 species were recorded by the Kinhill (1999) survey bringing the total number of recorded species to 316.

Western Australia and the Northern Territory have different requirements for the conservation of flora and, as the Project Area includes land in both Western Australia and the Northern Territory, the conservation requirements of each must be considered. Compliance with Western Australian and Northern Territory requirements would also allow for compliance with the *Endangered Species Protection Act 1992*.

Within Western Australia, rare flora is protected by the *Wildlife Conservation Act 1950*. The Act is administered by CALM and prohibits the taking of any Declared Rare Flora on any lands throughout Western Australia without the written consent of the Minister for the

Environment. CALM also maintains a supplementary listing of rare flora species referred to as 'Priority Flora'.

Rare flora in the Northern Territory is protected by the *Parks and Wildlife Act 1993*. This Act includes a schedule of protected plants (and animals) and a supplementary list of flora species.

Sixteen taxa known to occur within the Project Area have been listed by either the Western Australian or the Northern Territory Governments as being threatened, rare or poorly known (Table 7.5). An additional three taxa are listed by the Northern Territory as being restricted in Central Australia but common throughout the remainder of the Territory. Fourteen taxa considered to be rare within the Northern Territory were recorded within the Northern Territory portion of the Project Area, of which two are listed as Priority Flora in Western Australia. An additional two taxa of priority status were restricted to Western Australia.

The sixteen rare and priority species recorded by Ecologia (1997a) in the Project Area are listed in Table 7.6, together with the number of sampling sites, the vegetation associations and soils units in which these species were recorded.

Five of the seventeen vegetation associations identified by Ecologia (1997a) do not include any of the sixteen rare and priority plant species (vegetation associations 6, 12, 13, 16 and 17), and nineteen of the twenty-six soil types sampled do not include records of any of the sixteen rare and priority species.

Of the rare and priority species of conservation significance recorded by Ecologia (1997a) in the Project Area, fourteen species are not exclusive to the Kimberley region, and occur in other regions of Western Australia and the Northern Territory (Table 7.7).

Impacts on the flora of the Project Area from project development, and the management measures proposed to mitigate the impacts, are described in Chapter 10.

Connors et al. (1996) list species restricted to the Victoria–Bonaparte Biogeographic Region in the Northern Territory. These include *Acacia ditricha*, *Brachychiton tuberculatus*, *Goodenia malvina* and *Grevillea agrifolia* recorded from the Project Area. However, in Western Australia some of the species listed by Connors et al. are known to occur outside the Victoria–Bonaparte Biogeographic Region.

7.4 INTRODUCED FLORA

Eighteen introduced plants were recorded within the Project Area by Ecologia (1997a) and Kinhill (Appendix J). The most widely distributed introduced taxa recorded are *Passiflora foetida* var. *hispida* (wild passionfruit), *Echinochloa colona* (awnless barnyard grass), *Achyranthes aspera* (chaff flower) and *Stylosanthes hamata* (Caribbean stylo). Seven of the introduced plants have been declared noxious weeds under the *Agriculture and Related Resources Act 1976* in Western Australia, and the *Noxious Weeds Act 1978* in the Northern Territory; these are listed in Table 7.8. None of these are listed in the National Weeds Strategy (Agriculture and Resource Management Council of Australia and New Zealand et al. 1999).

Table 7.5 Conservation codes and distribution of taxa recorded within the Project Area

Flora taxa	Conservation code		Present in State or Territory			Recorded for cracking-clay soils
	WA	NT	WA	WA & NT	NT	
						✓ +
Largeleaf Kurrajong (<i>Brachychiton tuberculatus</i>)	P3	3r		✓		
A lily (<i>Caesia chlorantha</i>)	Nil	3r			✓	✓ +
Cleome (<i>Cleome uncifera</i>)	Nil	3r		✓		
Grubweed (<i>Corchorus fascicularis</i>)	Nil	3r		✓		✓ +
Barnyard grass (<i>Echinochloa kimberleyensis</i>)	P1		✓			
A sedge (<i>Fimbristylis laxiglumis</i>)	P2	3r		✓		✓
Blady grass (<i>Imperata cylindrica</i>)	Nil	3r		✓ #		✓ +
Cow vine (<i>Ipomoea</i> aff. <i>agrillicole</i>)	Nil	3r			✓	✓ +
Lindernia (<i>Lindernia tectanthera</i>)	Nil	3r		✓		
Plumbago (<i>Plumbago zeylanica</i>)	Nil	3r		✓ #		✓ +
Sorghum (<i>Sorghum grande</i>)	Nil	3r		✓		✓
Striga (<i>Striga squamigera</i>)	Nil	3k		✓		✓ +
Tacca (<i>Tacca maculata</i>)	Nil	3r			✓	
Camel bush (<i>Trichodesma zeylanicum</i>)	Nil	3r		✓ #		
A grass (<i>Triodia acutispicula</i>)	P3	Nil	✓			
Typhonium (<i>Typhonium liliifolium</i>)	Nil	3r		✓		✓
A daisy (<i>Vittadinia spechtii</i> var. <i>kimberleyensis</i>)	Nil	3r		✓		

Notes:

Western Australia:

P1 = Priority One—Poorly Known Taxa. Taxa that are known from one or a few (generally < 5) populations that are under threat.

P2 = Priority Two—Poorly Known Taxa. Taxa that are known from one or a few (generally < 5) populations, at least some of which are not believed to be under immediate threat.

P3 = Priority Three—Poorly Known Taxa. Taxa that are known from several populations, at least some of which are not believed to be under immediate threat.

Nil = Not priority status.

Northern Territory:

2K = Insufficiently known nationally.

3r = Rare, but not currently endangered or vulnerable, occurring in small populations, restricted to specific and localised habitats.

3k = Poorly known.

= Rare in Central Australia, common elsewhere (i.e. not significant flora in the 'Top End').

✓ = Species recorded from cracking-clay soils.

✓ + = Species recorded from cracking clay soils and additional soil units.

Source: CALM 1999, Darwin Herbarium and Herbarium Rare Checklist, Parks and Wildlife Commission of the Northern Territory 1997.

Table 7.6 Flora of particular or listed conservation significance in the Project Area

Significant species	Number of sites	Vegetation associations	Soil Unit
<i>Brachychiton tuberculatus</i>	1	2	6a, 7a, 8a
<i>Caesia chlorantha</i>	1	11	1,5
<i>Cleome uncifera</i>	2	1	6, Cockatoo
<i>Corchorus fascicularis</i>	15	8, 9, 10, 11, 14, 15	1, 4, 5, 5a, 5e, 6e, 9, 9c
<i>Echinochloa kimberleyensis</i>	1	3	7a
<i>Fimbristylis laxiglumis</i>		15	1, 5, 9a
<i>Ipomoea</i> aff. <i>agrillicole</i>	1	7	2, 7
<i>Lindernia tectanthera</i>	1	15	8a
<i>Sorghum</i> ? <i>grande</i> *	5	4, 10	1, 2b, 3a, 4, 4a
<i>Striga squamigera</i>	1	8	5e, 6e
<i>Tacca maculata</i>	1	1	6, Cockatoo
<i>Triodia acutispicula</i>	4	1,2	6, 6a, 7a, 8a, Cockatoo
<i>Typhonium liliifolium</i>	2	10, 11	1, 4
<i>Vittadinia spechtii</i> var. <i>kimberleyensis</i>	1	1	6, Cockatoo

* ? means insufficient material for positive identification, but believed to be that species.

Source: *Ecologia* (1997a).

Table 7.7 Occurrence of significant flora of the Project Area in Western Australia and the Northern Territory

Significant species recorded in the Project Area	Collection localities in Western Australia and Northern Territory	Number of collections in WA Herbarium*	Number of collections in NT Herbarium
<i>Brachychiton tuberculatus</i>	Endemic to the Kimberley in the Ord River region.	11	8
<i>Caesia chlorantha</i>	Limbunya, Petermann Reserve and Beetaloo Station.	0	4
<i>Cleome uncifera</i>	Nita Downs Station, south to upper Gascoyne River, and east to the Great Sandy Desert.	56	4
<i>Corchorus fascicularis</i>	Central Kimberley,	7	15
<i>Echinochloa kimberleyensis</i>	Black-soil swamps along the Ord River.	3	0
<i>Fimbristylis laxiglumis</i>	Black clay north of Kununurra.	1	4
<i>Ipomoea</i> aff. <i>agrillicole</i>	Connells Lagoon and Balbarini Station.	0	6
<i>Lindernia tectanthera</i>	Possibly endemic to the Kimberley region. Recorded from Mitchell Plateau, Napier, Broome Bay, Kununurra, Prince Regent River Reserve, and between Broome and Derby.	3	0
<i>Triodia acutispicula</i>	Endemic to the Kimberley region, Drysdale River and Cape Leveque.	10	0
<i>Sorghum grande</i>	Katherine, Mittlebah Station, Willeroo and Manbulloo Station.	0	7
<i>Striga squamigera</i>	Mt Nyulasy and Kununurra.	12	6
<i>Typhonium liliifolium</i>	Mitchell Plateau and Kalumburu Mission.	5	4
<i>Vittadinia spechtii</i> var. <i>kimberleyensis</i>	Possibly endemic to the Kimberley region, King Leopold Range and Prince Regent River Reserve.	1	0

* Does not include field collections made by *Ecologia* (1997a).

Table 7.8 Declared weeds recorded within the Project Area

Taxa	Western Australia	Northern Territory
Parkinsonia (<i>Parkinsonia aculeata</i>)	P1, P2	Class B
Spinyhead sida (<i>Sida acuta</i>)	P1	Class B
Flannel weed (<i>Sida cordifolia</i>)	P1	Class B
Calotrope (<i>Calotropis procera</i>)	P1, P2	Class B
Johnson grass (<i>Sorghum halepense</i>)		Class C
Hyptis (<i>Hyptis suaveolens</i>)		Class B
Star burr, goat's head (<i>Acanthospermum hispidum</i>)		Class B

Notes:

P1 = plants that cannot be introduced or spread.

P2 = plants that will be eradicated.

Class B = growth and spread of plants to be controlled.

Class C = plants not to be introduced into the Northern Territory—they are not known to exist but could pose a significant threat if introduced.

Source: *Ecologia* (1997a)

Black cracking-clay soil areas of the Project Area have not been significantly affected by weed invasion. However, an area in the south-west section of the Weaber Plain, currently utilised to drain excess water from ORIA Stage One and subject to permanent inundation, has been colonised by the native wetland plant cumbungi (*Typha domingensis*). This has resulted in the localised loss of some of the naturally occurring species adapted to seasonally wet sites.

The potential for weeds to invade neighbouring native vegetation after being brought into the Project Area (e.g. via agricultural or earthmoving machinery) has been assessed by examining the incidence of introduced species in and around ORIA Stage One. Herbicide use and mechanical weed control (tillage) have been effective in controlling weed infestations within farms in this area. However, some adjacent areas—including road verges, uncleared red and black-soil plains, river levees and channels—have been deleteriously affected by weed invasion originating from past agricultural activities.

There is the potential for weeds in ORIA Stage One to be transferred into the Project Area. This could include transfer by wind (e.g. calotrope [*Calotropis procera*]), or by the water movement from the Kununurra Diversion Dam to the Project Area (e.g. para grass [*Urochloa mutica*]).

The major weeds in the irrigation channels of ORIA Stage One are cumbungi (*Typha domingensis*) and lily or ribbon weed (*Vallisneria nana* [previously *Vallisneria spiralis*]). Weeds of the channel banks are caltrop (*Tribulus terrestris*), calotrope (*Calotropis procera*), johnson grass (*Sorghum halepense*) and para grass (*Urochloa mutica*). The invasion of the irrigation channels and balancing storage dams by *Vallisneria* and other waterweeds is inevitable. Two aggressive weeds that currently require control along and within the channels are ribbon weed (*Vallisneria nana*) and johnson grass (*Sorghum halepense*). Neither are listed Declared Weeds in Western Australia, but johnson grass is a Class C weed in the Northern Territory.

In addition to the analysis of weeds in ORIA Stage One, research has shown that there may be weeds from other areas which may potentially establish in the Project Area (S. Lloyd, pers. comm.). *Hymenachne amplexicaulis*, which establishes in water to 3 m deep and invades sugar fields, is a problem in Queensland. Two species, *Salvinia molesta* and the sensitive plant (*Mimosa pigra*), listed in the National Weed Strategy (1999) are of potential concern. *Salvinia molesta* (P1, P2 in Western Australia, noxious in the Northern Territory)

is an aggressive weed along watercourses in the Northern Territory and has been recorded and controlled in the Kimberley region. The sensitive plant (*Mimosa pigra*) (P1 in Western Australia, Class B in the Northern Territory), considered to be one of Australia's worst environmental weeds (Braithwaite et al. 1989), is a potential weed of floodplains. Sensitive plant (*Mimosa pigra*) is a problem in the Northern Territory (e.g. Kakadu) and is now in the Fitzmaurice River in the Northern Territory.

Chapter 10 provides a description of the management measures proposed to mitigate the introduction of weeds into the Project Area.

8 Existing environment—terrestrial fauna

This chapter describes the fauna of the Project Area, including fauna habitats and rare and protected fauna. Other chapters of relevance are Chapter 7, which describes the vegetation and flora; Chapter 9, which describes the aquatic flora and fauna; and Chapter 10, which describes the proposed conservation strategy for the Project.

8.1 REVIEW OF BIOLOGICAL SURVEYS

8.1.1 Regional overview

The Project Area falls within the Torresian Zoogeographic Region (Ecologia 1997a), the humid tropical and subtropical areas of northern Australia. This region incorporates the Kimberley region of Western Australia, much of the ‘Top End’ of the Northern Territory, and northern Queensland.

Most of the fauna encountered within the Project Area is adapted to the wet–dry tropical environment and has Torresian distributions (Ecologia 1997a). However, the distribution of some fauna is more wide-ranging, and some faunal elements have strong affinities with the Eyrean Biogeographic Region (semi-arid to arid areas). Other fauna, in particular birds, may be even more wide-ranging, with distributions throughout Australia or overseas, such as transequatorial migratory species.

8.1.2 Fauna surveys of the East Kimberley

The locations of fauna surveys undertaken outside of the Project Area, but within the east Kimberley include:

- Prince Regent River Nature Reserve (Miles and Burbidge 1975);
- Drysdale River National Park (Kabay and Burbidge 1977);
- Mitchell Plateau (Western Australian Museum 1981);
- Argyle Diamond Mine (Dames & Moore 1982);
- Kimberley rainforests (McKenzie et al. 1991);
- Purnululu National Park (Department of Conservation and Land Management 1992);
- ORIA Stage Two Riverside Developments, Kununurra (Ecologia 1997b);
- Lower Ord Ramsar site (Department of Conservation and Land Management 1998).

Surveys performed within the Project Area include:

- Ecologia (1997a)
- Larson (1999) (Appendix L)
- Kinhill (Appendix J).

Ecologia was commissioned by the DRD to undertake biological surveys of the Project Area as part of studies for an unpublished Public Environmental Report. Two surveys were undertaken by Ecologia; a dry season survey over fifteen days in October 1996 and a wet season survey over four days in February 1997.

Assessment of vertebrate fauna by Ecologia was made using a variety of trapping, searching and observational techniques. During the dry season eighteen systematic fauna survey sites were established. Pit traps were established at fifteen sites and Elliott traps at all eighteen. The duration of surveys was fifteen days. Additional sites were searched for reptiles and birds. During the wet season four days of limited trapping was undertaken together with avifauna transects. During field work all fauna sighted and secondary evidence of fauna such as tracks, diggings and scats were recorded. Additional fauna trapping techniques included nocturnal searching, mist netting, tortoise trapping and aquatic funnel trapping.

The Larson (1999) survey (Appendix L) was commissioned by Wesfarmers–Marubeni and the Water Corporation specifically to assess the aquatic fauna of the Project Area. This survey was undertaken in October 1998 and also included opportunistic recordings of terrestrial fauna (see Chapter 9).

The objectives of the Kinhill surveys, conducted in May and June 1999, were to provide additional information on the fauna utilising the black-soil plains of the Project Area.

The locations of terrestrial fauna sampling sites utilised by the Ecologia and Kinhill surveys in the Project Area are shown in Figure 8.1.

Ecologia (1997a) compared the findings of its survey of the Project Area with those of other prior fauna surveys of the east Kimberley region in order to evaluate the importance of the Project Area as a refuge for wildlife. The conclusions made by Ecologia were as follows:

- The number of bird species recorded from the Project Area is high, primarily due to the abundance of waterbirds.
- The diversity and number of reptiles in the Project Area is relatively low, primarily due to the lack of favourable rocky habitat.
- The number of amphibians in the Project Area is relatively high—greater numbers were only recorded on the Mitchell Plateau.
- Mammal species diversity and numbers are relatively low in the Project Area.

8.1.3 Fauna of cracking-clay environments

Cracking-clay environments of the black-soil plains are the dominant feature within the Project Area that would be affected by the proposed development. Discussion of the similarity that these areas have with other cracking-clay environments in the surrounding region is outlined below.

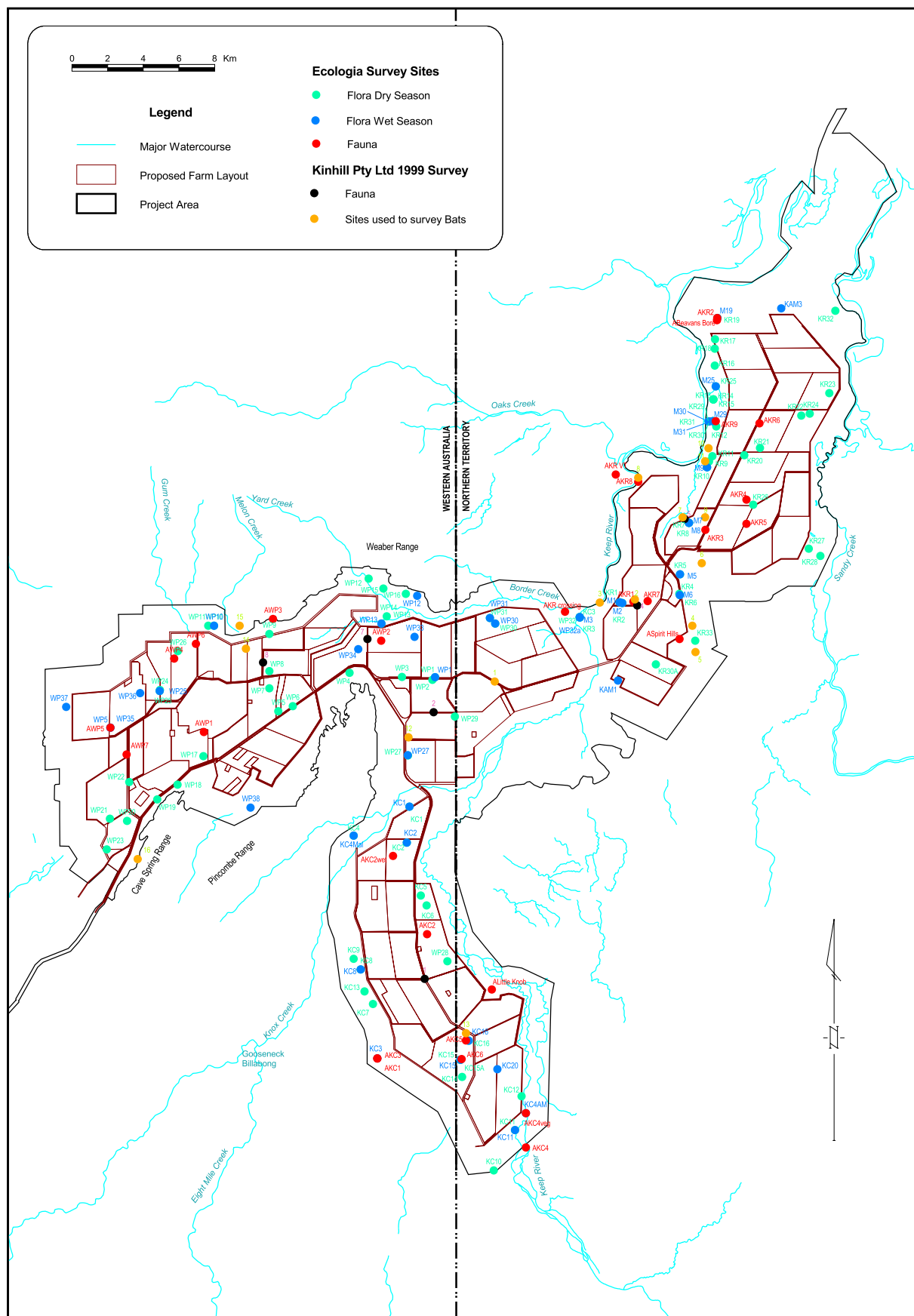


Figure 8.1 Map of fauna survey sites in the Project Area

An analysis of the Parks and Wildlife Commission of the Northern Territory's Fauna Atlas was carried out by Ecologia (1997a) for species preferentially inhabiting cracking-clay habitats. Eighty-seven vertebrate species that showed clear preferences for cracking-clay habitats were identified, as noted in Table 8.1. Also listed in Table 8.1 are those species endemic to cracking-clay soils.

Table 8.1 Vertebrate fauna of cracking-clay soils

Order	Number of records* for cracking clay (preference score > 2) [†]	Fauna species with a preference score > 4	Fauna species endemic to cracking clay
Amphibians	15	Black soil toadlet; Dahl's aquatic frog.	—
Birds	35	Red-chested button-quail, flock bronzewing, great crested grebe, grass owl, yellow chat.	—
Reptiles	30	<i>Diplodactylus tessellatus</i> ; <i>Tympanocryptis tetraporophora</i> ; <i>Ctenotus pulchellus</i> ; <i>Acanthophis antarcticus</i> ; <i>Demansia torquata</i> ; <i>Pseudonaja ingrami</i> . [‡]	<i>Ctenotus rimicola rimicola</i> ; <i>Ctenotus rimicola campestris</i> ; <i>Proablepharus kinghorni</i> . [‡] <i>Pseudodonaja guttata</i> ; <i>Varanus spenceri</i> .
Mammals	7	Long-haired rat; long-tailed planigale.	—

* Information taken from the Parks and Wildlife Commission of the Northern Territory's Fauna Atlas.

† A preference score was calculated for each species. This showed, for all the clay soil types, the degree to which the density of records was greater than the overall density of Northern Territory records for each species. However, these soil units were at a coarse scale and may contain significant areas of other soil types. A score greater than 1 indicates that particular species occurs on clay soils. A score > 2 indicates that species shows a preference for the cracking clay soil environment. Higher scores would therefore indicate a stronger preference.

‡ No common names available for these species.

Note: Preference score was calculated by dividing the density of records in clay map-units by the overall density of Northern Territory records. The clay map-units were obtained by using the Atlas of Australian soils (Northcote 1960).

In order to determine the broad biogeographic patterns of species distribution, the cracking clay soil units within the Northern Territory were divided by Ecologia (1997a) into seven geographic zones, all of which are east of the Project Area, and were compared on the basis of number and types of species recorded in each zone.

Ecologia (1997a) concluded from this comparison that the observed differences between the geographic zones are likely to be a reflection of the steep north–south climatic gradient in the Northern Territory, which has been shown previously to be a major influence affecting variation in faunal assemblages in north-western Australia (Woinarski 1992). A primary division could be made between the high rainfall coastal zones and low rainfall inland zones.

Ecologia (1997a) also concluded that other black-soil plains within the Victoria–Bonaparte Biogeographic Region, with a similar faunal composition to those in the Project Area, are likely to be those with a similar climatic regime. Based on rainfall isohyets, these areas occur within the Victoria–Ord area on the Ivanhoe, Legune, Dillinya or Willeroo land systems in a broad arc between Adolphus Island in the west and Mt Leonard in the east (Stewart et al. 1970).

8.2 FAUNA HABITATS OF THE PROJECT AREA

Fauna habitats are closely aligned with landforms and associated vegetation.

The original fauna survey of the Project Area was undertaken by Ecologia (1997a) and this work was augmented by further field survey work undertaken by Kinhill (1999).

Ecologia (1997a) recognised seven fauna habitats in the Project Area. Two of the habitats, eucalyptus woodland and bauhinia woodland, differ in their soil characteristics (red clays for eucalyptus woodland and black clays for the bauhinia woodland) and in the dominance of the tree species. The information provided for the Ecologia sites did not allow the separation of the two fauna habitats as the fauna sites listed by Ecologia are predominantly in the black soils. The red soils, Soil Units 2 and 3, are not abundant in the Project Area (Figure 4.3) whereas the black soils are dominant.

Kinhill (1999) consolidated the eucalyptus woodland and bauhinia woodland habitats as woodland, and recognised six faunal habitats in the Project Area (Table 8.2). Two of the habitats are widespread and broadly categorised as savanna woodland (grassland and woodland), while the remaining four are more restricted and provide more specialised habitats. For each habitat, examples of the soil unit and number of vegetation associations are listed for the Project Area. Figure 8.2 shows the distribution of fauna habitats within the Project Area.

Table 8.2 Fauna habitats in the Project Area

Habitat	Description	Soil Unit*	Vegetation associations [†]
Grassland	Grassland with scattered trees.	1, 3a, 5c, 5a, 5b, 4a, 6, 9c, 2b	G1–4, GT1–6, GT8–11, 13, 14
Woodland	Sparse eucalypt or open <i>Bauhinia cunninghamii</i> over grass on black soil (Cununurra clay).	1, 1g, 4b, 1c, 4d, 5, 5a, 5b, 5c, 5bt, 5e, 4a, 4c, 8, 8b, 9c, 8a, 6e, 1e, 8e,	Bc1–3, Cb3–5, Cb7–9, Cc2–4, Ct2, Em1, Em1–4, Em6–9, ET1, 3–6, Ex1–3, Me1
Riverine woodland	Closed woodland along river margins occurring on levees of sandy or loamy soils.	7, 7a, 7a/b, 7b, 7f	Cb1, Cb2, Cb6, Ep1, EM3, EM5, Ex4, Me2, Me3, G5, GT7
Vine thicket	Seasonally inundated forest adjoining Keep River.	7	EM3
Wetland	Billabongs and permanently inundated areas.	1, 5a, 5c/4d	GT9, G7, G6
Rock outcrops	Dolomite outcrops and sandstone scarps.	6, 6e, Cockatoo Dolomite, 11	CBG, Min1, Min2, GT14, EM2, Bo1, Tc1, GT10

* See Table 7.3.

† See Appendix J

Source: Kinhill Pty Ltd (1999).

The greater part of the habitat encountered in the Project Area and in the Gardner Botanical District of Beard (1979) consists of savanna woodland (Wheeler et al. 1992). This habitat occurs on the black-soil or red-soil plains. A description of the fauna habitats of the Project Area is provided below.

8.2.1 Grassland

Grass species common in this habitat include many species of *Sehima*, *Heteropogon*, *Sorghum*, *Triodia*, *Iseilema* and *Panicum*. Fauna species that commonly utilise the grassland habitat include agile wallaby (*Macropus agilis*), dusky rat (*Rattus colletti*) and star finch (*Neochmia ruficauda*). Several species are essentially restricted to this habitat, including singing bushlark (*Mirafra javanica*), golden-headed cisticola (*Cisticola exilis*) and an agamid

lizard (*Tympanocryptis uniformis*). This grassland habitat is typically found on soils inundated in the wet season and cracked in the dry season.

8.2.2 Eucalyptus woodland

Eucalypt woodland is grassland with few shrubs and emergent trees, dominated by *Eucalyptus* spp.; *Corymbia* spp. and *Bauhinia cunninghamii*. Birds, reptiles, amphibians and mammals are numerous, and common species include blue-winged kookaburra (*Dacelo leachii*), black-tailed treecreeper (*Climacteris melanura*), red-tailed black-cockatoo (*Calyptorhynchus banksii*), crested pigeon (*Ocyphaps lophotes*), frill-necked lizard (*Diporiphora magna*) and northern dwarf tree-frog (*Litoria bicolor*). Species recorded only from this habitat are the plumed whistling duck (*Dendrocygna eytoni*), southern boobook (*Ninox novaeseelandiae*), red backed kingfisher (*Todiramphus pyrrhopygia*), four lizards (*Proablepharus tenuis*, *Lerista griffini*, *Ctenotus rimicola rimicola* and an undescribed species of skink [*Morethia* sp. nov.]) and the long-footed frog (*Cyclorana longipes*).

8.2.3 Riverine woodland

The riverine woodland is a localised habitat, marked by an abundance and diversity of species. This habitat occurs along the margins of the Keep River, Knox Creek, Sandy Creek, Border Creek and on the levees adjacent to them, and is subject to inundation during the wet season.

When intact these areas serve a number of functions:

- they decrease the potential for erosion, and for organic matter to pass into streams and rivers;
- they provide habitats for aquatic species, waterbirds, stream-zone birds, amphibians, and semi-aquatic reptiles and mammals;
- they create a fauna corridor that facilitates movement of species for this area and the region.

Kitchener (1978) noted the absence of arboreal species in his survey of the Ord River area and this was also noted by Ecologia (1997a) in the Project Area. Kitchener (1978) suggested that the absence of this species group is due to the degradation of the riverine woodlands as a result of burning and of grazing pressure from cattle.

Kinhill (Appendix J) recorded nine species from the riverine areas. Species of rare and protected fauna (Section 8.5) recorded from riverine woodland habitat are white-browed robin (*Poecilodryas superciliosa*), radjah shelduck (*Tadorna radjah*), peregrine falcon (*Falco peregrinus*) and freshwater crocodile (*Crocodylus johnstoni*). Common species recorded are bar-shouldered dove (*Geopelia humeralis*), honeyeaters, pheasant coucal (*Centropus phasianinus*), dragon lizard (*Gemmatophora gilberti*) and frogs. Species recorded only from this habitat included azure kingfisher (*Alcedo azurea*), shining flycatcher (*Myiagra alecto*) and Roth's tree-frog (*Litoria rothii*).

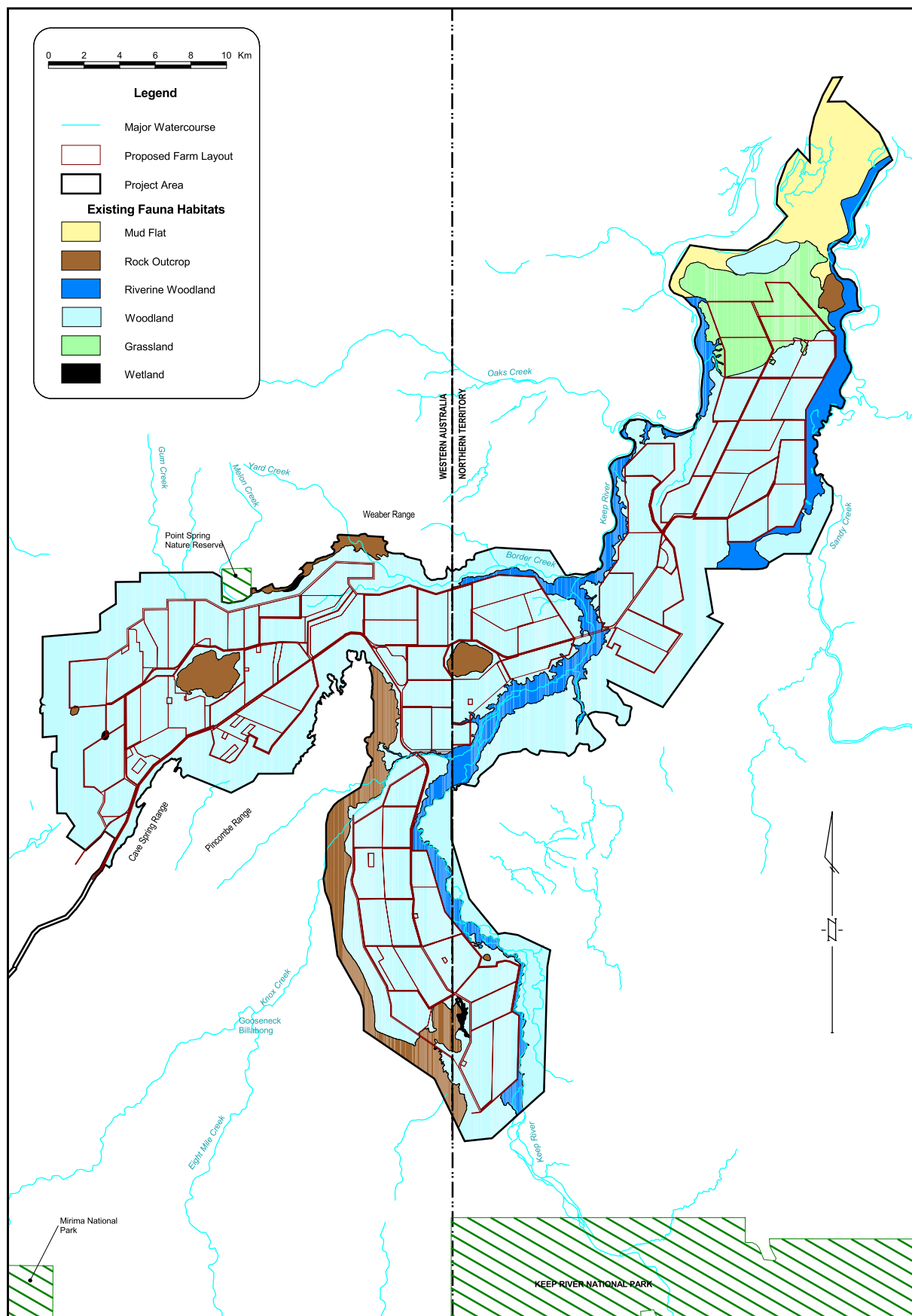


Figure 8.2 Fauna habitats in the Project Area

8.2.4 Vine thicket

Vine thickets occur in small localised patches within the Project Area and consist of a variety of tree and vine species. The thickets form a thick canopy, particularly in the latter stages of the wet season, and typically support a high diversity of flora and fauna due to their structural diversity and regionally atypical microclimate.

Bird species that are almost entirely restricted to this habitat include the P4 species (refer to Table 8.4) white-browed robin (*Poecilodryas superciliosa*) and yellow oriole (*Oriolus flavocinctus*). Commonly recorded species are nankeen night heron (*Nycticorax caledonicus*), sulphur-crested cockatoo (*Cacatua galerita*), restless flycatcher (*Myiagra inquieta*) and olive-backed oriole (*Oriolus sagittatus*).

8.2.5 Wetland

Wetlands in and adjacent to the Project Area include billabongs, permanently inundated areas, and artificial water storage areas (e.g. dams and tanks). These areas support a diverse array of vertebrate and invertebrate fauna species.

Wetland habitat is characterised by waterbirds such as darter (*Anhinga melanogaster*), Pacific heron (*Ardea pacifica*) and green pygmy-goose (*Nettapus pulchellus*). Migratory waders such as common sandpiper (*Actitis hypoleucos*) and grey-tailed tattler (*Heteroscelis brevipes*) occur, with finches, in the fringing vegetation. Mammals recorded are the dasyurid *Planigale ingrami* and Gould's wattled bat (*Chalinolobus gouldii*). An undescribed tortoise species (*Chelodina* sp. nov.) was recorded from Milligan Lagoon.

A flat-headed frog (*Limnodynastes depressus*) was recorded in December 1997 from Cockatoo Lagoon in the Keep River National Park, approximately 32 km south of the southern extent of the Project Area (Puckey et al. 1999). The habitat of this species is cracking-clay soil that is inundated during the wet season and previously it had only been collected in an area that was flooded to create Lake Argyle. It was more recently recorded as possibly occurring at Lisadell Station. A management plan is being prepared by the Parks and Wildlife Commission of the Northern Territory, and fieldwork will be undertaken by the Commission in 1999 to review the field status of populations and potential habitats of this species in the region.

8.2.6 Rock outcrops

Several rock outcrops occur throughout the Project Area, though none of these would be developed.

Rock crevices, loose rocks and small caves provide numerous niches for specialist saxicoline (rock-inhabiting) fauna species. Rock crevices may be utilised by geckos, while caves may be used as roosts for bats, or as shelter for a range of fauna. Species recorded only from this habitat include common rock rat (*Zyomys argurus*), ningbing pseudantechinus (*Pseudantechinus ningbing*), sandstone dtella (*Gehyra nana*), ridge-tailed monitor (*Varanus acanthurus*) and Copland's rock frog (*Litoria coplandi*). Six species of bats were recorded from caves or rocky areas (Kinhill Pty Ltd 1999; see Appendix J).

8.3 VERTEBRATE FAUNA

Based on desktop research, it is believed that the Project Area may support fifty-five native and eight introduced mammals species, 240 species of birds, 102 species of reptiles and twenty-seven species of frogs. Table 8.3 lists the major vertebrate species groups recorded from each of the fauna habitats in the Project Area.

Table 8.3 Summary of vertebrate fauna species* recorded in habitats of the Project Area

Fauna	Ecologia (1997a)								Total (including Kinhill 1999)
	Habitat								
	EW	BW	GR	RW	WE	RO	VT	Total	
Native mammals									
Number recorded	5	2	4	1	2	5	0	11	28
Introduced mammals									
Number recorded	1	0	0	1	0	1	0	2	2
Birds									
Number recorded	89	74	61	103	78	79	49	156	166
Reptiles									
Number recorded	18	10	4	7	4	13	1	36	45
Frogs									
Number recorded	9	7	5	6	2	5	1	15	20
Total number recorded	122	93	74	118	86	103	51	220	261

* All species confirmed with the Western Australian Museum.

EW = eucalypt woodland; BW = Bauhinia woodland; GR = grassland; RW = riverine woodland; WE = wetland; RO = rock outcrops; VT = vine thicket.

Source: Kinhill Pty Ltd (1999) and Ecologia (1997a)

8.3.1 Mammals

Ecologia (1997a) recorded thirteen species of mammals in the Project Area, including eleven native and two introduced species. Five families of native fauna were found to be represented in the Project Area, including Dasyuridae (carnivorous marsupials—two species), Macropodidae (kangaroos and wallabies—three species), Pteropodidae (fruit bats—one species), Vespertilionidae (true bats—three species) and Muridae (rats and mice—four species).

Larson (1999) recorded five mammal species near the Keep River. Four species had been listed as occurring in the region but not recorded by Ecologia (1997a) in the Project Area. These are short-eared rock-wallaby (*Petrogale brachyotis*), grassland melomys (*Melomys burtoni*), little red flying-fox (*Pteropus scapulatus*) and common sheath-tail-bat (*Taphozous georgianus*).

Kinhill Pty Ltd (1999) recorded (Appendix J) a second species of the family Dasyuridae (*Planigale maculata*), and thirteen species of bats not already recorded by Ecologia (1997a). Four of these bats had not previously been recorded in the region: orange leaf-nosed bat (*Rhinonycteris auranticus*), pygmy long-eared bat (*Nyctophilus walkeri*), inland broad-nosed bat (*Scotorepens balstoni*) and northern cave bat (*Vespedalus caurinus*).

Eight native mammal families have been recorded in the Project Area, comprising twenty-eight mammal species and eight introduced species. The recorded families included Dasyuridae (carnivorous marsupials—three species), Macropodidae (kangaroos and wallabies—four species), Pteropodidae (fruit bats—two species), Vespertilionidae (true

bats—nine species), Megadermatidae (ghost bats—one species), Hipposideridae (horseshoe bats—two species), Emballonuridae (sheath-tail bats—two species), Molossidae (freetail bats—one species) and Muridae (rats and mice—four species).

On the basis of known habitat preferences and species distributions, it is possible that up to thirty-two additional native and six additional introduced mammal species may utilise the Project Area, but it is likely that only a small proportion of these species would reside in the Project Area.

Analysis of site similarity for mammal species composition was undertaken by Ecologia (1997a). The results indicate that only sites occurring within rock outcrops and wetland habitats show a distinct difference from other habitat types. Wetlands and vine thicket habitats also would be expected to provide shelter and water for a wide range of mammals, although the field surveys by Ecologia did not find this to be the case. Analysis of the remaining habitat types, grassland, eucalyptus woodland, bauhinia woodland and riverine woodland, did not group fauna sampling sites according to habitat type. It is likely that the structural similarities between the habitat types will allow for mammal distribution across all of these habitats.

8.3.2 Birds

A total of 156 species of bird, including ninety non-passerines and sixty-six passerines, was recorded by Ecologia with fifty-four families of avifauna represented in the Project Area. Families with the highest species richness include Meliphagidae (honeyeaters—fourteen species), Accipitridae (kites, hawks and eagles—eleven species), Ardeidae (herons and egrets—nine species) and Passeridae (finches and mannikins—nine species). Larson (1999) recorded seven species listed by Ecologia as ‘expected to occur’ in the Project Area: osprey (*Pandion haliaetus*), sharp-tailed sandpiper (*Calidris acuminata*), bush stone-curlew (*Burhinus grallarius*), silver gull (*Larus novaehollandiae*), caspian tern (*Sterna caspia*), little shrike-thrush (*Colluricincla megarrhyncha*) and white-quilled rock-pigeon (*Petrophassa albipennis*). Two species not listed for the area by Ecologia (1997a)—forest kingfisher (*Todiramphus macleayi*) and satin flycatcher (*Myiagra cyanoleuca*)—were also recorded by Larson (1999). Kinhill (Appendix J) recorded jabiru (*Ephippiorhynchus asiaticus*). The total number of bird species recorded to date in the Project Area is 166.

On the basis of known habitat preferences, species distributions and searches of the Western Australian Museum fauna database and the Parks and Wildlife Commission of the Northern Territory Fauna Atlas, 239 species, comprising 149 non-passerines and ninety passerines, would be expected to occur within the Project Area. During the dry season when water is scarce, the wetland and riverine woodland habitats provide valuable refuges for birds. This is reflected by the highest levels of species richness being encountered in these areas (sixty-three and forty-one species respectively). By contrast, the grassland offers few dry-season habitats and a relatively uniform range of habitats for birds, and consequently has the lowest species richness (seventeen species).

During the wet season the widespread abundance of water allows for the dispersal of many species. During this period, structurally diverse habitats (vine thicket, eucalypt woodland and rock outcrop) had the highest species richness (thirty-five, twenty-nine and twenty-eight species respectively). Grassland had the lowest species richness (fifteen species), presumably due to the lack of structural diversity (and consequent limited number of ecological niches).

Analysis of site similarity for avian species composition was undertaken by Ecologia (1997a) for the dry and wet seasons. The results indicate that, during the dry season, the overall composition of the avifauna varies little between habitats within the Project Area. This is expected, given the mobile nature of birds and the structural similarity between some of the habitat types. The results also indicated that bird assemblages may be more habitat specific during the wet season, possibly due to an abundance of food sources allowing birds to specialise in their habitat selection.

8.3.3 Reptiles and amphibians

A total of thirty-six reptile and fifteen amphibian species was recorded from the Project Area by Ecologia (1997a). The majority of reptile species recorded were lizards, the most commonly represented families being the Scincidae (skinks—sixteen species), Gekkonidae (geckos—seven species) and Agamidae (dragons—six species). The majority of frogs observed during the survey were tree frogs (eleven species), including seven species of *Litoria*.

Based on desktop research of known species distributions and their habitat preferences, up to twenty-seven frog species (from two families) and 102 reptiles (from eleven families) may exist in the Project Area.

Five of the thirteen reptile species recorded by Larson (1999) had been listed by Ecologia (1997a) as possibly occurring in the Project Area. These are bauxite rainbow-skink (*Carlia amax*), Mertens's water monitor (*Varanus mertensi*), Mitchell's water python (*Varanus mitchelli*), Children's python (*Liasis childreni*) and common tree snake (*Dendrelaphis punctulata*). Kinhill (Appendix J) recorded three additional species not listed by Ecologia (1997a): *Varanus scalaris*, a *Ramphotyphlops* sp. and a *Demansia* sp. A total number of forty-five reptile species have been recorded to date for the Project Area.

Larson (1999) recorded eleven species of frogs. Four species recorded by Larson (1999) were listed as expected to occur but were not recorded by Ecologia (1997a). In addition, *Limnodynastes tasmaniensis* was collected by Kinhill in June 1999 (Appendix J). This is a species not listed by Ecologia (1997) as occurring in the Project Area. The total number of frog species recorded in the Project Area is twenty, representing 70% of the species likely to occur there.

Analysis of site similarity for reptile and amphibian species composition by Ecologia (1997a) for dry-season data indicated only limited separation of sampling sites into described habitats. Rock outcrop habitat showed the strongest grouping, these sites being distinguished by the specialist reptile species taking advantage of relatively unique ecological niches within the study area. Sites occurring within the wetlands or riverine woodlands were less clearly grouped; however, the presence of water specialists, the turtle (*Chelodina* sp. nov.) and the freshwater crocodile (*Crocodylus johnstoni*), differentiated this habitat. The remainder of the sites formed broad, undifferentiated groupings (i.e. grassland, eucalyptus woodland and bauhينيا woodland). The available ecological niches within these habitats are common, distributed in large areas and unlikely to restrict or control fauna distribution.

8.4 INVERTEBRATES

Limited surveying of invertebrates has been undertaken in the Kimberley Region. The University of Sydney is currently studying species at the Point Springs Nature Reserve, and Richards (1968) contains a list of species surveyed in ORIA Stage 1 during the early years of operation of the irrigation scheme. Most of the information available on insects relates to pests of the agricultural crops. The National Insect Collection at Canberra contains a total of 1380 separate species from the Kimberley Region.

No rare insects are recorded for the Project Area (P. Mawson, CALM, pers. comm. 1999).

A total of 163 pest species have been recorded in the Kimberley Region (Richards, 1968 and B.Thistleton pers.comm). Pest species are those insects that have been found to cause destruction, no matter how slight, either to crops or pastures, dwellings or possessions or to cause discomfort to humans. Trial plots of sugarcane at the Frank Wise Institute have shown the following insects as being pests:

- yellow-winged locust (*Gastrimargus musicus*)
- spur-throated locust (*Austracnis guttulosa*)
- grasshopper (*Valanga irregularis*)
- sugar cane army worm (*Leucania loreyi*)
- northern army worm (*Pseudaletia separata*)
- stem borer (*Saluria* sp.)
- scale (*Icerya* sp. nr. *aegyptica*)
- termites (*Microcerotermes serratus*)

In addition to the abovementioned insects, the following two species are known to be pests of sugarcane in Queensland:

- striped swarming beetle (*Rhyparida didyma*)
- giant termite (*Microcerotermes darwiniensis*).

Both of these species are known to occur in Western Australia but neither has so far proven to be a sugarcane pest in the State.

8.5 RARE AND PROTECTED FAUNA

Within the Project Area, faunal species that have been recognised as rare, threatened with extinction, or as having high conservation value are protected by law under Commonwealth, Northern Territory or Western Australian legislation.

Within Western Australia, scheduled fauna is protected under the *Wildlife Conservation Act 1950*. In addition, species are listed on CALM's Priority Fauna List, which includes species removed from the Scheduled Fauna List, and other species known from only a few populations or that are in need of monitoring. Within the Northern Territory, fauna is covered under Schedule 7 of the *Parks and Wildlife Conservation Act 1993*. At the national level, fauna is protected under the *Endangered Species Protection Act 1992*. CAMBA (China and Australia Migratory Bird Agreement) covers certain species of avifauna, particularly transequatorial waders. Migratory species are also protected through JAMBA

(Japan and Australia Migratory Bird Agreement) and the Australian New Zealand Environment and Conservation Council.

The vertebrate species considered rare and protected under Commonwealth, Northern Territory and State legislation that could be expected to be found within the Project Area are listed in Table 8.4.

Two species recorded in the Project Area are listed under the Commonwealth *Endangered Species Protection Act 1992*: the Derby white-browed robin (*Poecilodryas superciliosa*) is classified as endangered, and the ghost bat (*Macroderma gigas*) is considered vulnerable.

Black bittern (*Ixobrychus flavicollis gouldi*), recorded in the Project Area, is listed on Schedule 1 under the Western Australian *Wildlife Conservation Act 1950*. An additional four species recorded within the Project Area are listed under Schedule 4 of the Act: peregrine falcon (*Falco peregrinus*), radjah shelduck (*Tadorna radjah*), freshwater crocodile (*Crocodylus johnstoni*) and saltwater crocodile (*Crocodylus porosus*).

Table 8.4 Rare and specially protected fauna known or predicted to occur in the Project Area

Species name	Common name	Conservation status*					Species
		WA	NT	ESP	CAMBA	JAMBA	presence [†]
Mammals							
<i>Macroderma gigas</i>	Ghost bat	P3	7	V			D
Birds							
<i>Cisticola juncidis</i>	Zitting cisticola	P3	7				W
<i>Erythrotriorchis radiatus</i>	Red goshawk	1	7	V			R
<i>Erythrura gouldiae</i>	Gouldian finch	1	7	E			R
<i>Falco hypoleucos</i>	Grey falcon	1		R			R
<i>Falco peregrinus</i>	Peregrine falcon	4					D
<i>Falcunculus frontatus whitei</i>	Kimberley crested shrike-tit	1		E			R
<i>Ixobrychus flavicollis gouldi</i>	Black bittern	1					W
<i>Lonchura flaviprymna</i>	Yellow-rumped mannikin	1	7	IK			R
<i>Malurus coronatus coronatus</i>	Purple-crowned fairy-wren	1	7				R
<i>Oriolus flavocinctus</i>)	Yellow oriole	P4					D,W
<i>Plegadis falcinellus</i>	Glossy ibis				Listed		
<i>Poecilodryas superciliosa cerviniventris</i>	Derby white-browed robin	P4		E			D,W
<i>Rostratula benghalensis</i>	Painted snipe	P3					
<i>Tardona radjah</i>	Radjah shelduck	4					D,W
<i>Tringa brevipes</i>	Greytailed tattler				Listed		
<i>Tringa glareola</i>	Wood sandpiper				Listed		
<i>Tringa hypoleucos</i>	Common sandpiper				Listed		
<i>Tringa nebularia</i>	Greenshank				Listed	Listed	
<i>Tringa stagnatilis</i>	Marsh sandpiper				Listed	Listed	
Reptiles							
<i>Crocodylus johnstoni</i>	Freshwater crocodile	4		IK			D,W
<i>Crocodylus porosus</i>	Saltwater crocodile	4		IK			D
Amphibians							
<i>Cyclorana vagitus</i>	Wailing frog		7				W
<i>Litoria splendida</i>	Splendid tree frog		7				D
<i>Limnodynastes depressus</i>	Flat-headed frog						R

* WA = Schedules 1–4, Priority species P1, P2, P3, P4; NT = Schedule 7; ESP = Endangered Species Protection Act 1992; E = Endangered; V = Vulnerable; IK = insufficiently known; R = Rare.

† R = recorded in the Victoria–Bonaparte Biogeographic Region. D, W = recorded in the Project Area (dry and wet season respectively).

Ghost bat (*Macroderma gigas*), zitting cisticola (*Cisticola juncidis*) and wailing frog (*Cyclorana vagitus*) were also recorded within the Project Area, and are listed under Schedule 7 of the *Parks and Wildlife Conservation Action 1993*.

Flat-headed frog (*Limnodynastes depressus*) is classed as a critically vulnerable species in the Northern Territory. Two recently described subspecies—*Ctenotus rimicola rimicola* and *Ctenotus rimicola campestris*—were rated by the taxonomists Horner and Fisher (1998) as ‘rare or insufficiently known’ in both Western Australia and the Northern Territory.

Thirteen species listed under CAMBA and seven species listed under JAMBA are expected to occur in the Project Area. Two other CAMBA listed species that have been recorded in the Ord Valley are barn swallow (*Hirundo rustica*) and yellow wagtail (*Motacilla flava*).

Fifteen fauna species recorded or expected to occur in the Project Area, whilst not classified under Commonwealth or State Acts, have restricted distributions, have specialised habitat requirements or are recently named species. These species are as follows:

- Mammals: long-tailed planigale (*Planigale ingrami*), *Planigale maculata* and *Rattus colletti*.
- Birds: grass owl (*Tyto capensis*), lemon-bellied flycatcher (*Microeca flavigaster*) and king quail (*Coturnix chinensis*).
- Reptiles: *Ctenotus rimicola rimicola*, *Morethia* sp. nov., *Chelodina* sp. nov., Ord snake (*Suta ordensis*), *Demansia* sp. complex, and *Ramphotyphlops* sp. 2.
- Amphibians: Northern spadefoot (*Notadena melanoscapus*), Northern toadlet (*Uperoleia borealis*), blacksoil toadlet (*Uperoleia trachyderma*).

Chapter 10 describes the management strategies proposed to mitigate impacts upon fauna from development of the Project Area.

8.6 INTRODUCED SPECIES

Three introduced species—introduced but naturalised dingo (*Canis lupus dingo*), cat (*Felis catus*), and donkey (*Equus asinus*)—were recorded in the Project Area by Ecologia (1997a). The native rat (*Rattus villosissimus*) should also be present, and it occasionally reaches plague proportions in ORIA Stage One. Introduced rodents, such as house mouse (*Mus musculus*) and black rat (*Rattus rattus*), are also expected to occur within the Project Area. Other mammals expected to occur are horse (*Equus caballus*) and feral pig (*Sus scrofa*). Cattle (*Bos indicus*) are widespread across the Project Area as a result of pastoral lease operations.

9 Existing environment—aquatic flora and fauna

The proposed development allows for all rivers, streams and natural wetlands in the Project Area to be contained within conservation areas, and to be isolated from land development. This chapter describes the flora and fauna associated with surface water features within and near the Project Area. Other chapters of relevance are Chapter 5, which describes the existing and potential changes to the hydrology and water quality of these surface water features; Chapter 6, which describes the existing and potential groundwater scenarios, and effects that changes in groundwater may have on surface water; and Chapter 10, which describes the conservation strategy for the Project, potential impacts from development, and proposed management measures.

9.1 OVERVIEW

Relative to other areas of Australia there is limited literature available on the aquatic systems of the Kimberley region. Lane and McComb (1988) described the wetlands of the region in broad ecological terms, and Benson (1997) identified the wetlands within the Project Area. Molluscs have been studied by Wilson and Stoddart (1979); fish have been investigated by Allen (1982), Hutchins (1981) and Larson (1995, 1996, 1999); and waterbirds have been studied by Jaensch (1994). A marine biological survey of the eastern Kimberley has been undertaken by the Western Australian Museum and the University of Western Australia (Walker et al. 1996).

As described by Lane and McComb (1988), the types of natural wetland found in the Kimberley region include:

- perennial or intermittent rivers (mostly freshwater);
- estuaries subject to large seasonal changes in salinity brought about by the balance between seasonal intrusion of marine water, evaporation, rainfall and river discharge;
- ephemeral wetlands on rock outcrops;
- seasonal lakes and associated swamps. (These are common as there are very few permanent lakes.)

In addition, there are also artificial wetlands such as those formed in association with dams, irrigation water and water storage structures.

The Ramsar Classification (1990) groups wetlands into three major categories: marine and coastal, inland, and man-made/intensively farmed or grazed wetlands. Within the Victoria–Bonaparte Biogeographical Region there are two listed Ramsar sites—Lake Argyle and Lake Kununurra (jointly) and the Ord River Floodplain.

The Australian Nature Conservation Agency (ANCA) developed a system based on the original Ramsar Classification as modified for Australian conditions known as the ‘Directory of Important Wetlands in Australia’ (ANCA 1995). The directory details nominated wetlands and their present conservation status. The five wetlands listed for the Victoria–Bonaparte Biogeographical Region are the Ord Estuary, Parry Floodplain, Lake Argyle and Lake Kununurra and the Legune Wetlands. All these wetlands are outside the Project Area.

Benson (1997) modified the ANCA classification system when studying wetlands within the Project Area. Table 9.1 summarises the wetland classification and the number of wetlands identified by Benson (1997) within the Project Area (Figure 9.1).

Table 9.1 Wetland classification of the plains in the Project Area

ANCA classification	ANCA description	Weaber Plain	Knox Creek Plain	Keep River Plain
A	Marine and coastal zone wetlands			
A6	Estuarine wetlands, and permanent waters of estuaries and estuarine systems of deltas.	–	–	KEP3, KEP5, KEP9
B	Inland wetlands			
B2	Seasonal and irregular rivers and streams	WP1, WP2, WP3, WP4, WP5, WP6, WP8	KXP2, KXP3, KXP4, KXP5, KXP6, KXP9, XKP10	KEP2, KEP4
B4	Riverine floodplains, including river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna.	–	KXP8	–
B9	Permanent freshwater ponds (< 8 ha) and marshes and swamps on inorganic soils, with emergent vegetation waterlogged for at least most of the growing season.	–	KXP1	KEP1, KEP6, KEP7, KEP8
B10	Seasonal/intermittent freshwater ponds and marshes on inorganic soils, including sloughs, potholes, seasonally flooded meadows and sedge marshes.	WP9	KXP7	KEP10
C	Man-made wetlands			
C2	Ponds, including farm ponds, stock ponds and small tanks (generally < 8 ha).	WP10	–	–
C10	Drains	WP7		

Source: Benson (1997).

9.2 RIPARIAN VEGETATION

Throughout the Project Area the vegetation fringing the creeks, rivers and other watercourses is dominated by freshwater mangrove (*Barringtonia acutangula*), paperbark (*Melaleuca argentea*), screw palm (*Pandanus spiralis*), *Cathormium umbellatum*, wattle (*Acacia colei*) and rivergum *Eucalyptus* spp., including (*Eu. camaldulensis*) and guttapercha tree (*Excoecaria parvifolia*). These species are mainly associated with fresh or slightly brackish water. Scattered mangroves occur along the northern reaches of the Keep River within the Project Area, but extensive mangrove woodlands are located further downstream and outside the Project Area.

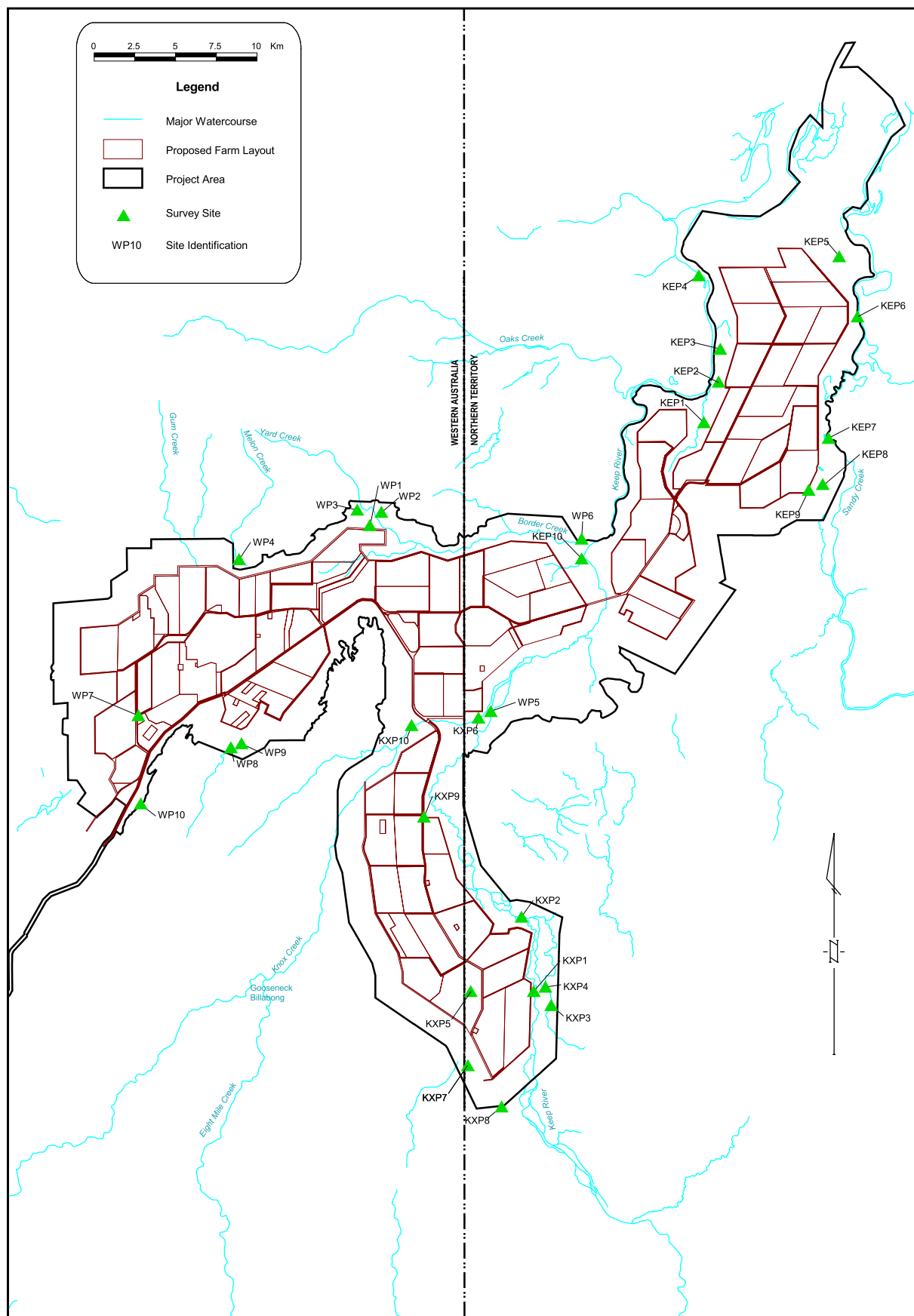


Figure 9.1 Wetlands surveyed by Benson within the Project Area

The riparian vegetation in or near to the Project Area recorded by Benson (1997) is summarised in Table 9.2.

9.3 AQUATIC VEGETATION AND FLORA

The records of the Western Australian Herbarium were used to determine which aquatic species were likely to occur in the Project Area. In addition, during the fauna study of the Keep River by Larson (1999), opportunistic recordings of aquatic plants were also made. Benson (1997) recorded only the riparian vegetation.

Table 9.2 Riparian vegetation of wetlands in or near to the Project Area

Watercourse or wetland	Dominant vegetation
Weaber Plain	
Border Creek (WP2, WP6)	<i>Melaleuca argentea</i> , <i>Melaleuca leucadendra</i> , <i>Barringtonia acutangula</i> , <i>Lophostemon grandiflora</i> , <i>Eucalyptus parvifolia</i> , <i>Acacia colei</i> and <i>Terminalia</i> sp.
Yard Creek (WP3)	<i>Barringtonia acutangula</i> , <i>Ficus opposita</i> , <i>Petalostigma pubescens</i> , <i>Terminalia oblongata</i> subsp. <i>volucris</i> and <i>Pandanus spiralis</i> .
Melon Creek (WP4)	<i>Barringtonia acutangula</i> , <i>Melaleuca argentea</i> , <i>Pandanus spiralis</i> , <i>Petalostigma pubescens</i> , <i>Terminalia oblongata</i> subsp. <i>volucris</i> , <i>Pandanus spiralis</i> and <i>Passiflora foetida</i> .
Knox Creek (WP5), WP6	<i>Eucalyptus</i> spp., <i>Excoecaria parvifolia</i> and <i>Cathormium umbellatum</i> .
Seasonal wetland—Cave Spring and Pincombe Ranges (WP9)	<i>Lophostemon</i> sp., <i>Acacia</i> spp. and <i>Eucalyptus</i> spp.
WP1, WP8, WP9	No riparian vegetation
Knox Creek Plain	
Milligan Lagoon (KXP1)	<i>Barringtonia acutangula</i> , <i>Excoecaria parvifolia</i> , <i>Corymbia bella</i> , <i>Eucalyptus</i> sp. and <i>Cathormium umbellatum</i> .
Overflow stream Keep River (KXP8)	<i>Cathormium umbellatum</i> , <i>Excoecaria parvifolia</i> , <i>Barringtonia acutangula</i> , <i>Eucalyptus camaldulensis</i> and <i>Corymbia bella</i> .
Seasonal wetland (KXP7)	<i>Excoecaria parvifolia</i> , <i>Eucalyptus</i> sp., <i>Adansonia gregorii</i> and <i>Bauhinia cunninghamii</i> .
Knox Creek (KXP10)	<i>Excoecaria parvifolia</i> , <i>Cathormium umbellatum</i> and <i>Eucalyptus</i> sp.
Unnamed tributaries (KXP3, KXP4,)	<i>Barringtonia acutangula</i> , <i>Terminalia</i> sp., <i>Melaleuca argentea</i> , <i>Eucalyptus camaldulensis</i> , <i>Corymbia bella</i> , <i>Cathormium umbellatum</i> , <i>Excoecaria parvifolia</i> , <i>Acacia colei</i> , <i>Lophostemon</i> sp. and <i>Bauhinia cunninghamii</i> .
Unnamed seasonal creek (KXP9)	<i>Cathormium umbellatum</i> , <i>Excoecaria parvifolia</i> , <i>Terminalia</i> sp., <i>Petalostigma pubescens</i> and <i>Hakea arborescens</i> .
Keep River (KXP2, KXP5, KXP6)	<i>Barringtonia acutangula</i> , <i>Pandanus spiralis</i> , <i>Eucalyptus camaldulensis</i> , <i>Eu. papuana</i> , <i>Terminalia grandiflora</i> , <i>Melaleuca argentea</i> , <i>Excoecaria parvifolia</i> , <i>Cathormium umbellatum</i> and <i>Acacia holosericea</i>
Keep River Plain	
Interconnected pools (KEP3)	<i>Barringtonia acutangula</i> , <i>Melaleuca argentea</i> , <i>Cathormium umbellatum</i> , <i>Excoecaria parvifolia</i> and <i>Lophostemon</i> sp. and <i>Passiflora foetida</i> .
Seasonal wetland (KEP5)	<i>Melaleuca argentea</i> , <i>Excoecaria parvifolia</i> , <i>Eucalyptus</i> sp. and <i>Parkinsonia</i> sp.
Permanent wetland (KEP9)	<i>Melaleuca viridiflora</i> , <i>Barringtonia acutangula</i> and <i>Eucalyptus camaldulensis</i> .
Sandy Creek (KEP6)	<i>Melaleuca argentea</i> , <i>Eucalyptus camaldulensis</i> , <i>Pandanus spiralis</i> , <i>Barringtonia acutangula</i> , <i>Acacia colei</i> , <i>Melaleuca acacioides</i> , <i>Excoecaria parvifolia</i> , <i>Cathormium umbellatum</i> and <i>Grevillea striata</i> .
Tributary Keep River (KEP1, KEP7)	<i>Melaleuca acacioides</i> and <i>Excoecaria parvifolia</i> .
Seasonal creek (KEP8)	<i>Cathormium umbellatum</i> , <i>Excoecaria parvifolia</i> , <i>Melaleuca leucadendra</i> and <i>Eucalyptus</i> sp.
Keep River (KEP2, KEP4, KEP10)	<i>Melaleuca argentea</i> , <i>Aegicera cornulatum</i> , <i>Pandanus spiralis</i> , <i>Barringtonia acutangula</i> , <i>Melaleuca argentea</i> and <i>Nauclea orientalis</i> .

Source: Benson (1997).

9.3.1 Freshwater vascular flora

Table 9.3 provides a listing of freshwater vascular plants that have been recorded in the vicinity of Kununurra.

Table 9.3 Freshwater vascular plant species recorded in the vicinity of Kununurra

Vascular plant species	Plant type	Habitat	Occurrence
<i>Brachyachne tenella</i>	Rooted	Shallow water, herbaceous swamp	Ord River floodplain
<i>Ceratopteris thalictroides</i>	Floating or rooted	Pools	15 km south of old Ord River Station
<i>Chionachne cyathopoda</i>	Rooted	Base of riverbank	Ord River
<i>Echinochloa macrandra</i>	Rooted	Swamps	Ord River
<i>Eleocharis</i> aff. <i>brassii</i>	Rooted	Shallow water, swamps, billabongs and lagoons	Kununurra and Lake Argyle
<i>Eleocharis sphacelata</i>	Rooted	Lagoons	Lower Ord River
<i>Eleocharis spiralis</i>	Rooted	Tidal pools	Lower Ord River
<i>Fimbristylis blakei</i>	Rooted	Springs	Lower Ord River
<i>Hydrilla verticillata</i>	Rooted	Stagnant or slow-flowing fresh water	Lower Ord River
<i>Ipomoea aquatica</i>	Floating or rooted	Floats on water or grows in mud along edges of creeks and drainage channels	Kununurra and Ord River
<i>Lygodium microphyllum</i>	Rooted	Swamps	Near Kununurra
<i>Marsilea mutica</i>	Floating or rooted	Pools and in water or on edge of watercourses	Plain of Ord River and Parry Lagoon
<i>Myriophyllum trachycarpum</i>	Rooted	Shallow water at edge of lakes	Lake Argyle
<i>Myriophyllum verrucosum</i>	Floating or rooted	Shallow water at edge of lakes	Lake Argyle and Lake Kununurra
<i>Najas graminea</i>	Rooted	Fresh water and swamps	Ord River and Kununurra
<i>Najas melesiana</i>	Rooted	Fresh water	Near Kununurra
<i>Najas tenuifolia</i>	Rooted	Fresh or rarely brackish, still or flowing water	Ord River, Lake Argyle and ORIA Stage One
<i>Nymphaea hastifolia</i>	Rooted	Ephemeral in creeks and billabongs	Ord River Basin
<i>Nymphaea violacea</i>	Rooted	Ephemeral or permanent water	Widespread in region
<i>Nymphoides indica</i>	Rooted	Still to flowing, permanent to near permanent water to a 1.3 m depth	Kununurra and Ord River
<i>Pandanus aquaticus</i>	Rooted	In and along watercourses	Ord River
<i>Pandanus spiralis</i>	Rooted	In and along watercourses	Ord River
<i>Potamogeton tricarinatus</i>	Rooted	Still or slowly flowing fresh water and drainage channels	Lake Kununurra, Ord River and Lake Argyle
<i>Salvinia molesta</i> *	Floating	Still or flowing fresh water	Kununurra (eradicated), but potential weed
<i>Tacca leontopetaloides</i>	Rooted	Pools	Point Spring
<i>Typha domingensis</i>	Rooted	Freshwater pools and streams	Ord River (widespread)
<i>Utricularia gibba</i>	Floating	Still pools or ephemeral swamps	Parry Lagoon
<i>Utricularia muelleri</i>	Floating	Ephemeral swamps	Kununurra
<i>Utricularia stellaris</i>	Floating	Still pools or ephemeral swamps	Parry Lagoon
<i>Vallisneria annua</i> (previously <i>Vallisneria spiralis</i>)	Rooted	Pools with water > 1 m deep, watercourses and drainage channels	Kununurra, Ord River and Packsaddle Swamp
<i>Vallisneria nana</i>	Rooted	Irrigation channels	Kununurra
<i>Wolffia angusta</i>	Floating	Pools	Parry Lagoon and Lake Kununurra

* Introduced species.

Source: Western Australian Herbarium florabase; Flora of the Kimberley Region (Wheeler 1992).

The list in Table 9.3 indicates the potential for aquatic plant species to occur in the pools, billabongs, creeks and rivers of the Project Area. Larson (1999) recorded the algae *Chara* spp. and *Enteromorpha* spp. Filamentous algae would also be expected to occur in waterbodies within the Project Area.

Gowland (1982) listed the common species of the littoral zone and those growing in the water of wetlands adjoining Lake Kununurra. He commented upon the rapid spread of cumbungi (*Typha domingensis*), which is replacing the native *Eleocharis* spp. The water around submerged vegetation also periodically supports blooms of an alga, *Eucaryota* spp.

Larson (1999) recorded the aquatic vegetation in the pools along the Keep River near the southern boundary of the Project Area as comprising:

- mixed grasses and nardoo (*Marsilea* sp.) in the water;
- spikerush (*Eleocharis* spp.) and taro (*Colocasia esculenta*) in the soil at the water's edge.

At Alligator Hole and Milligan Lagoon, Larson (1999) recorded waterlilies (*Nymphaea macrosperma* and *Nymphaea violacea*), water nymph (*Nymphoides indica*, *Najas tenuifolia*), bladderwort (*Utricularia australis*), water thyme (*Hydrilla verticillata*) and *Chara* spp.

9.3.2 Seagrasses and macroalgae

Little information is available on the estuarine and marine flora present or likely to occur in the northern Kimberley region. The turbid water at the river deltas and the abundance of crocodiles make the survey of estuarine and marine plants difficult and hazardous. The only major survey undertaken within the eastern Kimberley was a survey of eleven different locations, approximately 80 km from the Project Area, within the Cambridge Gulf in the northern Kimberley, by Walker et al. (1996); a summary follows.

Seagrasses

Three seagrasses were collected, with *Enhalus acoroides* having extensive cover at Cape Londonderry. Subtidal populations of seagrasses are not known, but it appears that the northern Kimberley does not have the seagrass richness recorded for the southern Kimberley. A similar survey of the southern Kimberley recorded eight species of seagrasses (Walker et al. 1996).

Macroalgae

Ninety species (Table 9.4) of macroalgae were collected. All reefs have a large number of *Sargassum* spp. (brown algae), and the rhizobenthic green algae are common on reefs with sediment pockets. Red algae are less diverse.

The diversity and abundance of the algal flora recorded were poor. This was probably due to the extreme tidal exposure, highly turbid waters which reduce light penetration, and the smothering of plants with sediment. In addition the effects of freshwater inundation and sediment load in the wet season are expected to be a major ecological factor controlling the distribution of macroalgae. The delta of the Keep River is similar to the Cambridge Gulf, so the abundance of species of macroalgae would be expected to be comparable.

Table 9.4 Macroalgae collected from the Cambridge Gulf, northern Kimberley

Macroalgae	Number of species recorded				
	Vancouver Point*	Cape Domett†	Lacrosse Island‡	Reveley Island#	Total at 11 sample sites
Phaeophyta (brown algae)	2	0	1	3	18
Chlorophyta (green algae)	1	4	2	6	35
Rhodophyta (red algae)	5	3	3	11	37
Total	8	7	6	20	90

* From Myrmidon Ledge, a sandy bay fringed by mangroves with rocks down to and below water level.

† An intertidal sandy beach with occasional rock platforms.

‡ A sandy beach and rocky peninsula.

A low sandy island with extensive sandbars and upper intertidal rocky shoreline, and a lower intertidal platform cemented together with coralline algae.

Source: Walker et al. (1996).

9.4 AQUATIC FAUNA

A survey of aquatic fauna in and near to the Project Area was undertaken in October 1998 (Larson 1999—see Appendix L). Seventeen sites were sampled along the Keep River and Sandy Creek.

This 1998 survey recorded five mammal, ninety-three bird, thirteen reptile, eleven frog and thirty-five fish species. The mammals, birds, reptiles and frogs recorded by Larson (1999) are described in Chapter 8. Larson (1999) states that the aquatic invertebrates comprise assemblages typical of Northern Territory rivers, creeks and billabongs. Insects and molluscs are common in most waterbodies and some insects are locally common.

9.4.1 Sponges

Larson (1999) recorded a bright green sponge, possibly a *Radiospongilla* spp., growing on the limestone rocks in the Keep River and on the aquatic vegetation and rocks at Alligator Hole and Milligan Lagoon.

9.4.2 Fish

Based on fish distributions and drainage patterns, Australia may be divided into nine regions (Allen 1982). The richest inland faunal region—in terms of the number of species—is the Leichardian region, which includes the Kimberley, the northern portion of the Northern Territory and the Gulf of Carpentaria drainage of Queensland. Approximately 18% of the species found there are also recorded from southern New Guinea, indicating that the fish fauna of northern Australia is closely allied to that of New Guinea (Allen 1982). The Kimberley region contains forty principal species, of which sixteen (37.5%) are endemic to the region (Table 9.5).

Table 9.5 Distribution of endemic species of freshwater inland fishes in Western Australia

Distribution of inland fish	Number of endemic species
Kimberley	16
Northern Australia – southern New Guinea	10
Widespread tropical Australia	8
Unique to the south-west	8
Western Australia and the Northern Territory	5
Unique between Murchison and De Grey rivers, Western Australia	4
North Australia and Indo-Malayan Archipelago	2
Widespread Southern Hemisphere	1
Common to Western Australia, South Australia, Victoria and Tasmania	1

Source: Allen 1982.

The fish fauna of the Keep River is diverse and numerous, primarily due to the low level of commercial and recreational fishing. A total of thirty-five freshwater and estuarine fish species was recorded by Larson (1999). No introduced fish species were recorded, although the mosquito fish (*Gambusia holbrooki*) is widespread in many river systems in Western Australia and is known from streams north of Broome (Arthrington and Lloyd 1989).

Freshwater fish

Twenty-five species of freshwater fish were recorded from the Keep River and Sandy Creek areas (Larson 1999) and an additional fourteen species have been recorded as occurring in past surveys. Hutchins (1981) in a survey of the Mitchell Plateau and Admiralty Gulf recorded fourteen freshwater fish species, together with a further seven species that must return to estuarine waters to complete their life cycle. Gowland (1982) recorded sixteen fish species from the Lake Kununurra wetlands.

Allen (1982) recorded thirty-one freshwater fish from the Ord River, Lake Argyle and Lake Kununurra, and from the Kimberley area in general. Some of these species were not recorded in the Larson survey but are expected to occur there.

To the east of the Keep River there have been thirty-five species recorded from the Wickham River and forty-four from the Alligator River system. However, in a six-day survey of the Wickham River, twenty of the thirty-five species were recorded (Larson, in prep.), and in a nine-day survey, twenty-five of the forty-four species from the Alligator River system were recorded (Larson 1995). This demonstrates that additional fish species would be expected to occur in the Keep River.

Estuarine fish

Larson (1999) recorded ten species in her 1998 survey, although access for sampling was at times limited. By comparison, in a survey of estuarine and marine species in the Roper River, Larsen (1996) recorded 96 species. A total of 181 fish species are known from the estuaries and coasts within Kakadu National Park (Larson 1997), the Roper River estuary and nearby creeks (Larson 1996). With better access, the Keep River and Sandy Creek could be expected to resemble the Roper River and Alligator River estuaries and may have 100 or more estuarine species.

Threatened fish species

Two species of sawfish have been recorded in the Keep River—dwarf sawfish (*Pristis clavata*) and freshwater sawfish (*Pristis microdon*). Dwarf sawfish is coastal in distribution but can travel long distances up rivers into fresh water. Its conservation status is unknown but it may only occur in northern Australia. Freshwater sawfish is listed under the Commonwealth *Endangered Species Protection Act 1992* as ‘vulnerable’, as well as being listed as ‘Endangered’ in the International Union for Conservation of Nature and Natural Resources (IUCN) Red List (Larson 1999), and as ‘Potentially threatened’ in the 1998 Australian Society for Fish Biology’s Threatened Fish List (1998). It is usually located in fresh water and in the upper reaches of estuaries, and may be isolated in small billabongs for several years until floods release it back into the estuary. It has been recorded from several rivers in Western Australia, the Northern Territory and at Cape York in Queensland.

9.4.3 Crustaceans

Four crustacean species were recorded by Larson (1999) in the Keep River. Two species of freshwater prawns, *Macrobrachium rosenbergii* and *Macrobrachium bullatum*, are common. Wilson and Stoddart (1979) recorded freshwater crab (*Holtuisiana transversa*), freshwater prawns (*Macrobrachium rosenbergii*, *M. tolmerum* and *M. australiense cristatum*) and atyid shrimps (*Caridina* spp.) in their survey of the Keep River.

9.4.4 Molluscs

Wilson and Stoddart (1979) undertook a survey of the freshwater molluscs of the Ord River region to determine their potential as vectors of trematode parasites. A total of sixteen mollusc species was recorded from the five collecting trips (Table 9.6). Six different habitats were sampled and five of these were further separated into permanent or temporary water. The collections were centred on Kununurra, Lake Argyle and Keep River.

Larson (1999) recorded five species of molluscs from the Keep River and only one of these, *Austropeplea lessoni*, was not recorded by Wilson and Stoddart (1979). The freshwater mussel *Velesunio angasi*, which is abundant in the Kimberley region, was recorded from the Keep River in the Northern Territory. This is a new locality record for this species in the Northern Territory. None of these species are gazetted rare or priority species.

To determine if the distribution of species varied with the season, Wilson and Stoddart (1979) revisited many of the sampling sites. In permanent and temporary habitats there was little noticeable variation. Recently filled wetlands often had no live snails. The most commonly located snails were *Gyraulus essingtonensis* and *Amerianna carinata*, both occurring in ten out of the eleven sample sites.

Table 9.6 Habitat types and occurrence of mollusc species in the Ord River region

Species name	Dams		Rivers		Pools		Irrigation		Creeks		Swamps	Total
	P	T	P	T	P	T	P	T	P	T		
	(10)	(4)	(13)	(8)	(6)	(9)	(8)	(3)	(4)	(30)	(6)	(101)
Gastropods												
<i>Gyraulus essingtonensis</i>	6	3	3	3	1	4	2	2	1	13		38
<i>Amerianna carinata</i>	3	3	2	4	1	5	2	1		8	3	32
<i>Amerianna vinosa</i>			1	1		6	3	3	1	12	2	29
<i>Ferrissia petterdi</i>	1	1	2	3			1	1		7		16
<i>Thiara australis</i>	6		7				2					15
<i>Bayardella johni</i>				3						7		10
<i>Notopala essingtonensis</i>	2	1	3	2	1							9
<i>Notopala alisoni</i>						4				2	3	9
<i>Physastra badia</i>						3					5	8
<i>Bithynia australis</i>		2				4	1					7
<i>Isidorella sisurnia</i>										7		7
Bivalves												
<i>Velesunio angasi</i>	1		1							3		5
<i>Velesunio wilsoni</i>		1	1		3							5
<i>Corbicula</i> sp.	2			2								4
<i>Lortella rugata</i>							1					1
<i>Lortella froggattii</i>										1		1
Snails												
			4		2		2		2	1		11
Total	21	11	20	18	6	26	12	7	2	60	13	196

Note: P = permanent water; T = temporary water. The number of sample sites at each location is shown in brackets.

Source: Wilson and Stoddart (1979).

9.4.5 Insects

Larson (1999) recorded twenty-three insect species as detailed in Table 9.7. Most are common throughout northern Australia. However, other groups of the tabled species could be expected within the Project Area if additional surveys were undertaken. These include mayflies (Ephemeroptera), dragonflies (Odonata), caddisflies (Trichoptera), Hydrometridae (Hemiptera) and Gyrinidae (Coleoptera).

Halse et al. (1996) undertook a survey of water birds and invertebrates in the swamps of the Victoria–Bonaparte mudflats to the north of the Project Area. These mudflats form a band 10–20 km wide along the coast of the Joseph Bonaparte Gulf, between Cambridge Gulf in Western Australia and the north of the Victoria River in the Northern Territory. At least 131 species of invertebrates were collected during the survey. The number of species per site ranged from thirteen to sixty and a significant number of these were undescribed. The species-rich orders were Cladocera (twenty-seven species), Ploimida (twenty-four), Coleoptera (twenty), Copepoda (ten) and Ostracoda (ten).

Kay et al. (1999) sampled aquatic invertebrate fauna in the rivers of north-western Australia. The sites sampled closest to the Project Area were at Wilson Creek, Bamboo Creek and the Durack River, all more than 100 km from the Project Area.

Table 9.7 Insect species recorded in or near to the Project Area

Insect order and family	Number of species in Australia	Number of species in the Northern Territory	Number of species recorded
Hemiptera—bugs			
Belostomatidae (giant water-bugs)	4	2	1
Corixidae (water boatman)	31	2 genera	1
Galastoceridae (toad bugs)	23	3	1
Gerridae (water striders)	32	20	5
Nepidae (water scorpions)	8	7	3
Notonectidae (backswimmers)	40	3 genera	3
Coleoptera—beetles			
Dytiscidae (predaceous diving beetles)	185	54	6
Hydrophilidae (water scavenger beetles)	175	Many	1
Noteridae (burrowing water beetles)	5	Most	1
Orthoptera—grasshoppers and crickets			
Tridactylidae (pygmy mole crickets)	9	2	1

Source: Brown and Larson 1999.

9.4.6 Marine fauna

Table 9.8 lists the marine animals collected or observed from a survey of eleven different sites in the northern Kimberley (Walker et al. 1996).

Table 9.8 Marine fauna recorded in the northern Kimberley

Phylum	Number of species
Molluscs	194 gastropods; 62 bivalves; 2 chitons; 6 cephalopods; 1 scaphopod
Crustaceans	157 decapods; 1 conchostracan; 3 Thoracicans; 2 amphipods; 16 isopods; 2 stomatopods
Fish	194 marine and estuarine fish

Source: Walker et al. (1996).

The inshore Kimberley molluscan fauna is depauperate in comparison with other areas in the number of species, possibly due to the restricted number of habitats, lack of extensive coral reef fauna, and silty conditions. The crustacean fauna showed a higher diversity, and this diversity increased markedly at the estuarine sites and at well-developed mangrove communities (Walker et al. 1996).

A survey of the molluscan fauna of the Admiralty Gulf and nearby islands by Wells (1981) recorded 144 species, of which sixty-two were recorded from Point Warriedar. This site at the head of the Admiralty Gulf has a habitat similar to that described at the mouth of the Keep River, including rocky shores interspersed with deeply indented bays lined with mangrove swamps and extensive mudflats. There is no fresh water flowing through this area, except after heavy rains. The water is extremely turbid at low tide with a visibility of 15 cm or less, and as the tide rises, visibility increases to 1 m. Generally it was found that the molluscan fauna was site-specific. Fourteen gastropods and four bivalves were recorded from the mangrove swamps, of which only two bivalves live in the muddy substrate, the remainder living on the mud surface.

9.5 STYGOFAUNA

Stygofauna is the name given to fauna (usually invertebrate) that live exclusively in subterranean habitats. The stygofauna of Western Australia is largely unknown and predominantly undescribed.

The dispersion of stygofauna within an alluvial aquifer, as occurs in the Project Area, and as opposed to a karst of fissured aquifers, is likely to be widespread. However, individual species within alluvial aquifers are likely to have patchy distributions owing to local variations in groundwater characteristics.

The distribution of stygofauna is related, *inter alia*, to rock and sediment types, and the geological structure. Stygofauna habitat is best developed in karstic aquifers, but these are restricted in the Project Area to limestone formations beneath the western portion of the Knox Creek Plain. Stygofaunal habitat may also occur in unconsolidated sediments, if suitable water-filled voids are present. In unconsolidated sediments, the water-filled voids between grains of sediment, especially where these are sand-sized or larger, form an extensive groundwater habitat (porous aquifer). Thus stygofauna may be present in gravels and sands of the palaeochannels found under much of the Project Area (Chapter 6).

Thirty-four sampling locations were examined in the region from 1994 to 1998 by the Western Australian Museum of Natural Sciences (Appendix M). Of these, eleven sites contained stygofauna and another two sites contained fauna that was considered stygal. The sites ranged from the karstic limestone Devonian Reef system (Ningbing Range) outside of the Project Area, to the alluvial aquifers associated with the former course of the Ord River through the Ivanhoe Plain, Cave Spring Gap and the Weaber Plain. No sampling was undertaken in the Keep River Plain or the Knox Creek Plain although there could be Devonian/Carboniferous limestone underlying the western Knox Creek Plain of the Project Area.

The alluvial aquifers underlying the Ivanhoe Plain and ORIA Stage One contain undescribed species of stygofauna in two families of bathynellid syncarid Crustacea. The fauna from aquifers beneath the Cave Spring Gap and the Weaber Plain have similar characteristics, however it is unknown whether the fauna from this area is the same as that from the Ivanhoe Plain.

The groundwater salinity varies widely in different parts of the Project Area and this may have a major impact on the fauna it can support. While stygofauna is typically associated with freshwater (Gibert et. al. 1994), it is found in salinity of seawater strength in both near coastal aquifers (Humphreys in press b) and in the Yilgarn (W.F. Humphreys and H.J. Hahn, unpublished 1999).

Of marine origin, syncarids are one of the oldest groups of freshwater fauna. The Bathynellacea probably occupied surface freshwater in the Carboniferous and subsequently became restricted to living in the interstitial spaces in subterranean waters.

Syncarids are considered to be rare, but this may be due to the relatively low incidence of biological sampling of their subterranean habitat (Schminke 1986). Recent work in the Yilgarn has found both a high diversity and large populations of syncarids in calcrete aquifers (W.F. Humphreys and H.J. Hahn, unpublished 1999). The biology of syncarids is virtually unknown.

Of the two new species of syncarid Crustacea (H.K. Schminke pers comm.), belonging to two families (Bathynellidae and Parabathynellidae) taken in the groundwater of the ORIA, one is a species of *Atopobathynella* (Parabathynellidae). The recent findings of the genus in the arid (Barrow Island; Humphreys in press a) and monsoonal tropics of Western Australia (ORIA Stage One) suggests that syncarids of the genus *Atopobathynella* may be expected throughout Australia, at least in areas not inundated by the sea during the Cretaceous.

The fissured and karstic aquifers adjacent to the Knox Creek Plain are potential sources of stygofauna and, as they lie outside any immediate impact of the Project, could be potential buffer zones for subterranean fauna.

10 Biological environment—impacts and management

This chapter assesses the potential impacts that the proposed development may have on the biological environment of the Project Area, and the proposed mitigation of any impacts through environmental management and conservation of biodiversity within the Victoria–Bonaparte Biogeographic Region. Potential impacts and their management are considered in light of the current Western Australian, Northern Territory and Commonwealth conservation legislation and policies.

10.1 LEGISLATION AND POLICY FRAMEWORK FOR ENVIRONMENTAL MANAGEMENT

This section details the policy framework used to review the environmental impacts of, and proposed conservation management actions for, the Project. The legislation relevant to conservation management is identified in Table 10.1.

Table 10.1 Conservation management legislation

Western Australia	Northern Territory	Commonwealth
<i>Conservation and Land Management Act 1984</i>	<i>Environmental Assessment Act 1994</i>	<i>Environment Protection (Impact of Proposals) Act 1974</i>
<i>Environmental Protection Act 1986</i>	<i>Heritage Conservation Act 1996</i>	<i>National Parks and Wildlife Conservation Act 1975</i>
<i>Wildlife Conservation Act 1950</i>	<i>Parks and Wildlife Commission Act 1995</i>	<i>National Environment Protection Council Act 1994</i>
	<i>Territory Parks & Wildlife Conservation Act 1996</i>	<i>National Environment Protection Measures (Implementation) Act 1998</i>
		<i>Environment Protection and Biodiversity Conservation Act 1999</i>
		<i>Endangered Species Protection Act 1992</i>
		<i>Fisheries Resources Management Act 1994</i>

There are a number of national strategies that relate to environmental management. Those of most relevance to the proposed development are described in Section 10.1.1. In addition, the EPA Assessment guidelines specify biodiversity parameters to be addressed in relation to the proposed development (Appendix A), and those parameters are reproduced in Section 10.1.2. Processes that are currently threatening biodiversity in Australia are described in Section 10.1.3.

Wesfarmers–Marubeni and the Water Corporation are committed to effective management of environmental issues associated with the Project, consistent with the principles of sustainable development as outlined in the national strategies.

10.1.1 National strategies for environmental management and their implications for the Project

The National Strategy for Ecologically Sustainable Development

The National Strategy for Ecologically Sustainable Development (ESD) was endorsed by the Council of Australian Governments in December 1992. The principal objectives of ESD are to:

- enhance individual and community wellbeing and welfare by following a path of economic development that safeguards the welfare of future generations;
- provide for equity within and among generations;
- conserve biological diversity and maintain essential ecological processes and life-support systems.

These principles, which are being incorporated in various Government and private sector programmes, are the foundation for improved environmental management. They also address issues such as environmental liability and due diligence.

Environmental due diligence requires the application of best-practice environmental management, and includes the preparation, implementation and monitoring of a variety of documented controls, such as Environmental Management Plans (EMPs).

Environmental Management of the Project Area would be based on ESD principles. An EMP would be prepared for the Project, incorporating all the commitments made in this ERMP/draft EIS as well as any Ministerial Conditions. The EMP would also include elements of environmental management systems that have been specifically designed to improve environmental performance and achieve ESD. This would involve implementation of an environmental management system consistent with the principles of the International Standards Organisation ISO 14000 series.

The National Strategy for Conservation of Biological Diversity

Conservation of biodiversity is one of the three principal elements of ESD. The International Convention on Biological Diversity, adopted by Australia in June 1993, provides a global mechanism for the conservation of biodiversity for the benefit of present and future generations. Within Australia, the National Strategy for the Conservation of Australia's Biological Diversity (Commonwealth of Australia 1996) aims to bridge the gap between current activities and the effective identification, conservation and management of Australia's indigenous biological diversity.

The National Strategy for the Conservation of Australia's Biological Diversity (NSCABD) considers biological diversity at three levels: genetic diversity, species diversity and ecosystem diversity. The strategy contains six target areas:

- conservation of biological diversity across Australia
- integration of biological diversity, conservation and natural resources management

- management of threatening processes
- improvement of the knowledge and understanding of biodiversity
- involvement of the community
- Australia's international role regarding the conservation of biodiversity.

NSCABD notes the following key principles:

- Biological diversity is best conserved *in situ*.
- Although all levels of Government have clear responsibility, the cooperation of conservation groups, resource users, indigenous peoples, and the community in general is critical to the conservation of biological diversity.
- It is vital to anticipate, prevent, and attack at source the causes of significant reduction or loss of biological diversity.
- Processes for, and decisions about, the allocation and use of Australia's resources should be efficient, equitable and transparent.
- Lack of full knowledge should not be an excuse for postponing action to conserve biological diversity.
- The conservation of Australia's biological diversity is affected by international activities and requires actions extending beyond Australia's national jurisdiction.
- Australians operating beyond national jurisdiction should respect the principles of conservation and ecologically sustainable use of biological diversity, and act in accordance with any relevant national or international laws.
- Central to the conservation of Australia's biological diversity is the establishment of a comprehensive, representative and adequate system of ecologically viable protected areas integrated with the sympathetic management of all other areas, including agricultural and other resource production systems.
- The close, traditional association of Australia's indigenous peoples with components of biological diversity should be recognised, as should the desirability of sharing equitably benefits arising from the innovative use of traditional knowledge of biological diversity.

National Wilderness Inventory

The Commonwealth Government initiated the National Wilderness Inventory in 1986. The World Heritage Branch of Environment Australia administers the National Wilderness Inventory, and it defines wilderness as:

'...land that, together with its plant and animal communities, is in a state that has not been substantially modified, and is remote from, the influences of European settlement or is capable of being restored to such a state, is of sufficient size to make its maintenance in such a state feasible, and is capable of providing opportunities for solitude and self-reliant recreation.'

Four criteria are used to estimate the quality of wilderness. These are:

- remoteness from settlement;
- remoteness from access;

- apparent naturalness (lack of permanent structures);
- biophysical naturalness (degree of biophysical disturbance such as grazing, logging, and mining).

The above criteria are used to define Wilderness Quality ratings. The Wilderness Quality rating for the Project Area, and the impact of development, are discussed in Section 10.4.9.

10.1.2 Requirements of the EPA

The guidelines for this ERMP/draft EIS (Appendix A) were developed by the EPA and DLPE following the assessment of comments from the public on a set of draft guidelines. In the guidelines, the EPA has stated that its consideration of the Project's impact on biological diversity is to focus on the principles, and the related objectives and actions, of the NSCABD. It follows that the EPA's consideration of biological diversity would include:

- comparing a number of development scenarios to evaluate protection of biodiversity at the species and ecosystem levels;
- ensuring that no known species of plant or animal would become extinct as a consequence of the development and that any risk posed to threatened species is considered acceptable;
- ensuring that no association or community of indigenous plants ceases to exist as a result of the proposed development;
- ensuring there is comprehensive, adequate and secure representation of scarce or endangered habitats within the Project Area and/or in areas that are biologically comparable to the Project Area within Western Australia and the Northern Territory, protected in secure reserves;
- ensuring that the Project Area includes a comprehensive and adequate network of conservation areas and linking corridors whose integrity and biodiversity are secure and protected;
- identifying the on-site and off-site impacts of the proposed development and verifying that the co-proponents could manage those impacts.

Because of the size of the Project, the EPA considers that the co-proponents alone may not be able to protect biological diversity. The EPA has indicated that participation of the Western Australia and Northern Territory Governments in regional land use initiatives may be necessary to address biodiversity issues, and that further conservation reserves may be required outside the Project Area and, presumably, within the Victoria-Bonaparte Biogeographic Region. This issue is discussed further in Section 10.2.2.

10.1.3 Native title implications

In 1998, the Federal Court determined that Miriuwung and Gajerrong people have certain native title rights over a portion of the Project Area (Chapter 12 refers). Furthermore, native title claims exist over the remainder of the Project Area, and over much of the land surrounding the Project Area.

The native title determination includes the right to possess, occupy, use and enjoy the land and resources subject to the determination area.

Wesfarmers–Marubeni and the Water Corporation have recognised the need to involve Miriuwung and Gajerrong people in the consideration of biodiversity issues in relation to the proposed development. Some resources, including the vegetation that would need to be cleared to enable the development of the farmland, would be adversely affected by the proposed development. Such impact is unavoidable. Any loss of, or impairment to, the use of flora or fauna and other resources by Miriuwung and Gajerrong people would be addressed in an Indigenous Land Use Agreement (ILUA) to be negotiated between the Co-proponents and the Miriuwung Gajerrong people (Chapter 12 refers). The potential involvement of Miriuwung and Gajerrong people in the management of the biodiversity resource in the conservation areas within and abutting the Project Area is discussed in Section 10.5.1.

10.1.4 Management of biodiversity in the Australian context

Effective management of natural systems for the conservation of biodiversity requires an understanding of the systems being managed and processes likely to impact those systems. An understanding of the biological environment of the Project Area has been gained through biological surveys (see Chapters 7 to 9). Issues relevant to the *Endangered Species Protection Act 1992* include:

- a marked decrease in geographic distribution of species. This could be a decrease in the total area of the community without a species range contraction, a decrease in a species range within a given area, or fragmentation of the species range;
- a marked alteration of community structure. This includes the identity and number of species making up an ecological community, abundance of those species and the number, type and strength of processes operating within the community;
- a loss or decline of native species that are believed to play a major role in the community. This refers to important structural components of a community or those species that are important in the processes of a community;
- restricted geographic distribution such that the community could be lost within ten years by the action of a threatening process. This is determined at a national level and is dependent on particular species communities;
- community processes being altered to the extent that a marked alteration of community structure will occur. Ecological processes are important to maintain an ecological community (e.g. fire regimes, flooding, cyclone damage) and disruption to these processes can lead to significant alteration of an ecological community.

Threatening processes, as identified in NSCABD, are listed below. Also listed are brief references to the processes relevant to the proposed development. The processes include:

- *land clearing*—Clearance of native vegetation is an inevitable consequence of the proposed development. Land clearing would be minimised, but consistent with the objective of establishment of an economically viable industry. Representative samples of ecologically viable vegetation associations would be conserved *in situ*;
- *land degradation*—Degradation usually occurs as a consequence of inappropriate agricultural activities, and may include overstocking, rising groundwater levels and salinisation. The proposed groundwater management strategy is described in Chapter 6;

- *inappropriate fire regimes*—Formalised fire management practices do not currently occur in the Project Area. Such practices would be introduced as part of the EMP;
- *spread of alien species*—This may include the spread of exotic (introduced) species and native species outside of their normal range. Monitoring and management of weeds would be an element of the EMP;
- *global climate change*—It is not envisaged that global climate change would affect land use in the Project Area in the short or long term. The potential contribution made by the proposed development to national commitments made under the Kyoto Protocol are discussed in Chapter 13.

10.2 EXISTING AND PROPOSED RESERVES IN THE VICTORIA-BONAPARTE BIOGEOGRAPHIC REGION

Three classes of conservation reserves are recognised in Western Australia under the *Land Act 1984* in addition to National Parks. National Parks offer the highest level of environmental protection, while Class A reserves offer the highest level of environmental protection under the *Land Act 1984*, and parliamentary consent is necessary to downgrade this form of land classification. For land designated Class B or Class C, the Minister for Lands is able to unilaterally make changes to the designated purpose; however, in the case of Class B land, Parliament must be advised of the change within two weeks.

Northern Territory parks and reserves are declared as parks under Section 12 of the *Territory Parks & Wildlife Conservation Act 1996*. The Parks and Wildlife Commission of the Northern Territory classifies the parks according to purpose and function, namely, national parks, nature parks, conservation reserves, historical reserves and marine parks.

10.2.1 Current reserve system

The Victoria–Bonaparte Biogeographic Region has a total area of 72,970 km², with approximately 73% of this area in the Northern Territory and 27% in Western Australia. Within the Victoria–Bonaparte Biogeographic Region, the area in conservation reserves in the Northern Territory is 6,846 km² or approximately 13%; in Western Australia, the area in conservation reserves is also approximately 13% (2,443 km²).

Connors et al. (1996) reviewed each biogeographic region within the Northern Territory including the indigenous vegetation types, plants and animals restricted to each biogeographic region, and also introduced plants and feral animals. This level of information is not available for Western Australia and, therefore, only information about that part of the Victoria–Bonaparte Biogeographic Region in the Northern Territory is provided in Table 10.2.

A summary of the existing conservation reserves within the Victoria–Bonaparte Biogeographic Region in Western Australia and the Northern Territory is presented in Table 10.3. The locations of the reserves are shown in Figure 10.1.

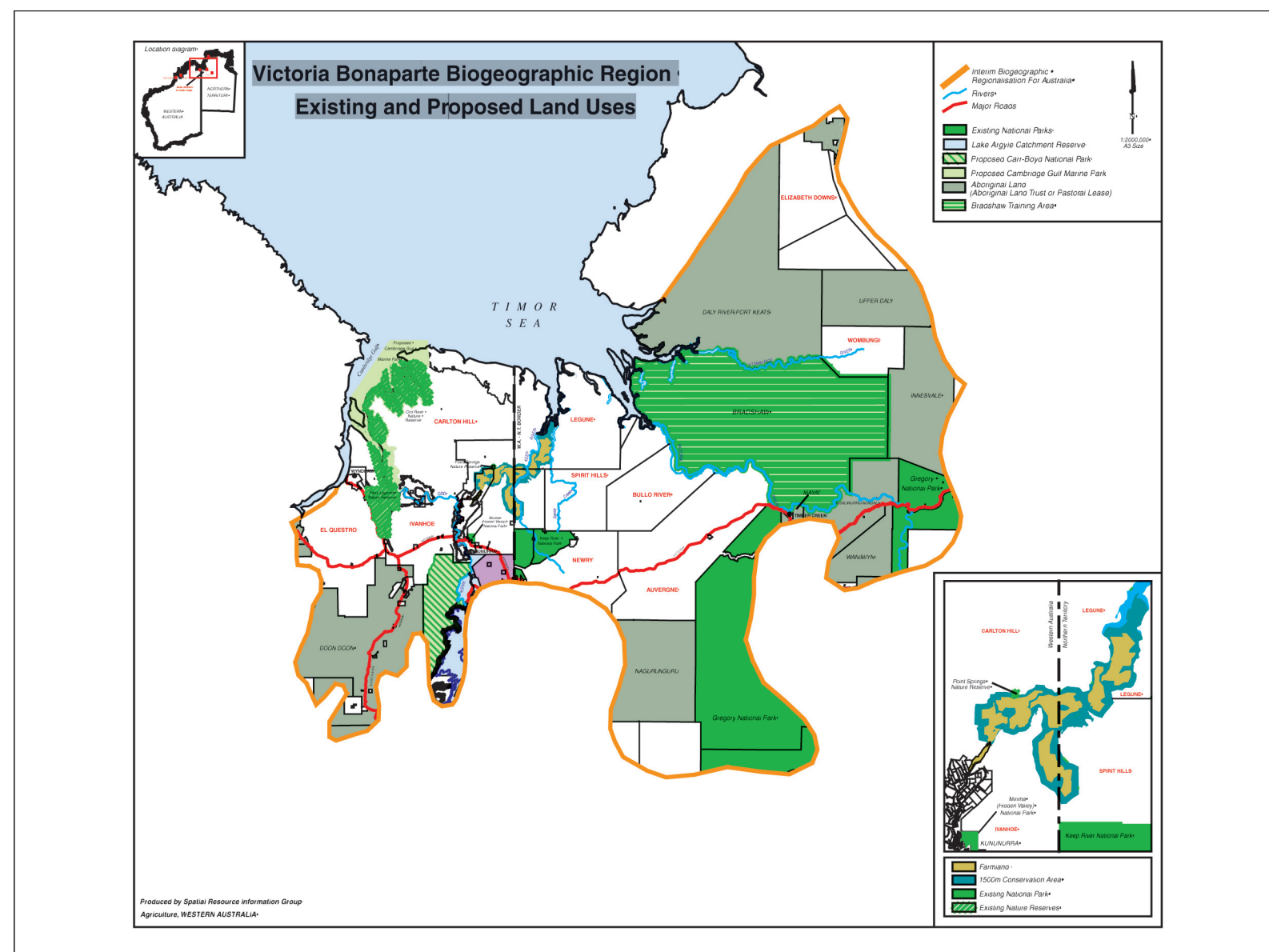


Figure 10.1 Victoria–Bonaparte Biogeographic Region - existing and proposed land uses

Table 10.2 Vegetation types in the Northern Territory portion of the Victoria–Bonaparte Biogeographic Region and their representation within reserves

Vegetation type	Area (km ²)	Area in reserves (km ²)	Proportion in reserves (%)
Closed forest	49	0	0
Eucalypt forest and woodland with tussock grass understorey	17,765	1,729	10
Eucalypt low woodland with tussock grass understorey	2,381	6	0
Eucalypt woodland with hummock grass understorey	23,176	4,947	21
Mixed species low open woodland	387	150	39
Melaleuca forest/woodland	4,117	1	0
Floodplain	47	0	0
Hummock grassland	29	0	0
Tussock grassland	2,442	13	0
Littoral complex	2,845	0	0
Total	53,238	6,846	13*

Source: Connors et al. (1996)

* Proportion of the total area of the Victoria–Bonaparte Biogeographical Region in reserves.

Lake Argyle and Lake Kununurra were formed as a result of the ORIA development and are listed under the Ramsar Convention as valuable habitat for aquatic birds, including migratory birds. The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. There are presently 116 Contracting Parties to the Convention, with 1005 wetland sites, totalling 71.3 million ha, designated for inclusion in the Ramsar List of Wetlands of International Importance.

The dominant species which make up the fringing grasslands of Lake Argyle and Lake Kununurra are *Eriachne sulcata*, *Echinochloa kimberleyensis* and *Oryza australiensis*, and a large number of ephemeral herbs (Burbidge et al. 1991). *Echinochloa kimberleyensis*, a Priority 1 species endemic to the Ord River area, was also recorded from the Project Area.

The cracking-clay black-soil plains within the Project Area would be the predominant soil type subjected to development. Within the current reserve system, in Western Australian and the Northern Territory, there are limited areas of cracking-clay black-soil plain. Table 10.4 lists the major features and soils for each of the reserves within the Victoria–Bonaparte Biogeographic Region.

Table 10.3 Existing conservation reserves and wetlands included on the Ramsar List of Wetlands of International Importance within the Victoria- Bonaparte Biogeographic Region and adjoining areas

Name of reserve	Area	Class; vesting	Comments
Western Australia			
Mirima National Park	2,068 ha	National Park; National Parks and Conservation Authority	Alongside Kununurra township. Striking scenery. Formerly named Hidden Valley National Park.
Ord River Nature Reserve*	79,842 ha	Class C; National Parks and Conservation Authority	Tidal portion of the Ord River, 25 km north-east of Wyndham, and includes the false mouths of the Ord River. Important bird, crocodile and mangrove habitat. Some boundaries classified as 40 m above high-water mark and some areas require fencing to control cattle access.
Parry Lagoons Nature Reserve*	36,111 ha	Class C; National Parks and Conservation Authority	25 km south-east of Wyndham. An easily accessible recreation site with outstanding birdlife.
Point Spring Nature Reserve	303 ha	Class A; National Parks and Conservation Authority	40 km north-east of Kununurra. A permanent wetland with remnant rainforest.
Eastern shore of Lake Argyle and Lake Kununurra	149,140 ha	Ramsar-listed wetland; National Parks and Conservation Authority	Spectacular scenery and wetlands.
Packsaddle Swamps	860 ha	Ramsar listed wetland; National Parks and Conservation Authority	5 km west of Kununurra. Spectacular scenery, wetlands and wildlife.
Northern Territory			
Keep River National Park	> 67,481 ha	Conservation of natural and cultural heritage; PWCNT	East of Kununurra and south of the Project Area. A significant planned expansion is to include Spirit Hills Station pastoral lease.
Gregory National Park	>1,278,304 ha	Conservation of natural and cultural heritage; PWCNT	Approximately 50% is within the Victoria-Bonaparte Biogeographic Region. Primarily rocky upland country, with minor areas of cracking-clay soils. Extensions are under consideration, and a draft management plan is being prepared.

* Now combined into the Lower Ord Ramsar Site (Department of Conservation and Land Management 1998).

Notes: National Parks and Nature Conservation Authority Information was supplied by the CALM Information Management Branch. The Ord River Nature Reserve, Parry Lagoons Nature Reserve, Proposed Parry Lagoons National Park and Proposed Cambridge Gulf Marine Park are now included in the Lower Ord Ramsar Site.

Information on the Keep River National Park and Gregory National Park was supplied by the Parks and Wildlife Commission of the Northern Territory (PWCNT).

Information on Lake Argyle, Lake Kununurra and Packsaddle Swamps is from Department of Conservation and Land Management (1990).

Table 10.4 Environmental features of Conservation Reserves and Ramsar Convention listed wetlands within the Victoria–Bonaparte Biogeographic Region

Name of site or area	Environmental features	Soils present
Western Australia		
Mirima National Park	Sandstone hills, Ord River sandplains.	Alluvial red and yellow sandplains of the Ord River.
Ord River Nature Reserve	Coastal and estuarine deltaic plains, incised deltaic creeks, deep sandy soils and mudflats.	Coastal silt, minor limestone, conglomerates; black soils and alluvium.
Parry Lagoons Nature Reserve	Wetlands; water table at or near surface in dry season, flooded during wet season.	Extensive areas of black soil.
Point Spring Nature Reserve	Permanent spring; rainforest.	Sandstone and black soil.
Lake Argyle and Carr Boyd Ranges*	Flood plains, deep alluvial drainage valleys of river system.	Black soil with heavy texture, red and yellow earths with coarse texture, small areas of basalt, granite and dolerite.
Packsaddle Swamps	Inundated and exposed fluvial plains.	Black and red soils.
Northern Territory		
Keep River National Park	Dissected plateau, alluvial plains and river systems, and fluvial plains.	Sandstone tablelands, red and yellow earths and black soil.
Gregory National Park	Wetlands, alluvial plains and river systems, limestone hills, sandstone escarpments, climatic transition between tropical and semi-arid regions.	Sandstone and limestone hills, ferricrete, black soils.

* The Carr Boyd Ranges are proposed under System 7 for national park status.

The Keep River National Park is the only reserve in the Victoria–Bonaparte Biogeographic Region with black-soil plains of the Ivanhoe Land System. However, there are black-soil plains outside the Victoria–Bonaparte Biogeographic Region to the west and the north of the Bungle Bungle massif in Purnululu National Park. These plains support significant areas of grasslands dominated by *Astrelba* species (Mitchell grasses). *Astrelba squarrosa* grassland was one of the vegetation associations in the Project Area recommended for conservation by Ecologia (1997).

10.2.2 Proposed reserve system

As signatories to the National Strategy for the Conservation of Australia’s Biological Diversity (Section 10.1.1), the Western Australian, Northern Territory and Commonwealth Governments are committed to the establishment of a comprehensive and representative system of ecologically viable protected areas. Following development, the Project Area would include undeveloped areas that would be managed for conservation. These conservation areas would not be formal conservation reserves; however, they would still provide an important contribution to the conservation estate.

The Governments of Western Australia and the Northern Territory continually review their systems of conservation reserves. As a consequence of these reviews, a number of proposals for the expansion of the conservation reserve system within the Victoria–Bonaparte Biogeographic Region are under consideration. The proposed development would provide significant opportunities for the State and Territory Governments to increase conservation

areas, particularly as these initiatives could be completed in parallel with the excisement of the Project Area from existing pastoral leases.

Western Australia

The Parry Lagoons Nature Reserve is a Class C reserve for the conservation of flora and fauna. A proposal exists for an expansion of this conservation reserve by approximately 3,400 ha, and a reclassification of the reserve to National Park status.

A National Park is also proposed for Lake Argyle and the Carr Boyd Ranges (Item 7.10 of the red book for conservation, and System 7 and Item 3.3 of the CALM publication 'Nature Conservation Reserves in the Kimberley'). This crown land, and Lake Argyle, is listed as a Ramsar wetland of international importance. The area of the proposed national park is 125,000 ha.

Northern Territory

The Northern Territory Government is considering a significant conservation initiative immediately adjacent to the Project Area. The initiative is the proposed extension of the Keep River National Park. The proposed extension of the Keep River National Park would result in an expansion of the conserved area in the Victoria–Bonaparte Biogeographic Region of approximately 220,000 ha.

10.3 CONSERVATION WITHIN THE PROJECT AREA

10.3.1 The need for conservation areas within the Project Area

The Project Area is predominantly located on black-soil plains (cracking clays) of the Ivanhoe Land System. Although there is some representation of this land system in other parts of Western Australia and the Northern Territory, these other areas:

- are generally poorly represented in conservation reserves;
- are predominantly subjected to pastoral activities and are consequently degraded;
- have different topography to that in the Project Area;
- are separated geographically from the Project Area and are therefore likely to differ biologically due to broad-scale climatic and geological differences.

As discussed in Section 10.2.2, the Northern Territory Government is considering a significant extension of the Keep River National Park, which would encompass most of the Spirit Hills Station pastoral lease (Parks and Wildlife Commission of the Northern Territory 1998b). If successful, this would extend the Keep River National Park up to the western side of the mouth of the Victoria River.

The Bradshaw Field Training Area north of Timber Creek in the Northern Territory has eleven land systems, including the Ivanhoe Land System (Connell Wagner 1997). The cracking-clay soils of this area consist of 'deep to very deep grey and brown cracking clays on the floodplains and drainage depressions', and 'grey and brown cracking clays along the Angalarri River and meander plain'. These soils support a low open woodland or grassland, similar to sections of the Project Area. However, the Bradshaw Field Training Area does not include the cracking clays of the Cununurra normal phase, which characterise the soils

proposed for development within the Project Area. Furthermore, the areas of the Ivanhoe Land System within the Bradshaw Field Training Area would be primarily utilised as fire and manoeuvre areas for armoured vehicles, and only small pockets would remain undisturbed.

Since the Project Area has a wider range of flora and fauna of conservation significance (see Sections 7.3 and 8.5) than other areas of the Ivanhoe Land System currently conserved, it is considered appropriate that conservation of certain habitats is planned within the Project Area.

10.3.2 Conservation strategy for the Project Area

The key environmental and conservation management objective in relation to the proposed development is the management of a world-class broad-scale agricultural development, with integral conservation areas, in accordance with Australia's ESD and biodiversity policies. The conservation management would involve many issues, such as indigenous habitats and species, traditional land uses, community involvement, water and land pollution, construction and operational activities, and pest species.

The objectives of the conservation management would be to:

- minimise environmental disturbance consistent with development requirements;
- maintain and not degrade the biological integrity and diversity in the Project Area and adjacent regions/areas;
- manage areas to the satisfaction of the community and Governments.

The priorities for environmental management of the Project Area are to:

- protect scheduled and other significant species, including those protected under international agreements;
- preserve site or habitat-specific areas;
- sustain biological diversity in terms of species richness criteria;
- conserve genetic resources;
- control erosion.

These priorities have been considered in the context of representation of scheduled species and suitable habitats in conservation reserves in the East Kimberley and the adjacent Northern Territory.

In designing a conservation strategy for the Project Area, an assessment was made of the best spatial arrangement that would efficiently represent the conservation values within the Project Area and satisfy the conservation and environmental management objectives. The conservation system proposed for the Project Area is outlined in Figure 10.2.

A key element of the conservation strategy is the retention of representative associations and habitats of the Project Area within distinct conservation areas. It is envisaged that native title rights would prevail over all conservation areas within the Project Area. The following sections provide a brief description of the rationale underlying selection of the conservation areas.

Conservation areas were selected using the following criteria:

- representation of soil types
- representation of vegetation units and fauna habitats
- presence of rare and endangered and vulnerable flora and fauna
- area of Aboriginal significance.

Northern sector of the Weaber Plain (Conservation Weaber North, CWN)

Area CWN would include levee banks together with additional land that has been incorporated into the project design to insulate Point Spring Nature Reserve (a place of cultural significance to Miriuwung and Gajerrong people) from the anticipated higher flood water levels and flow velocities in Border Creek. It also includes the lower slopes of the Weaber Range, and would provide protection for fauna and flora in this locality.

Wild rice (*Oryza australiensis*), *Echinochloa kimberleyensis*, *Fimbristylis phaeoleuca*, *Goodenia malvina* and *Enteropogon minutus* would all be conserved in this area.

Soil Units conserved are 2c, 4c, 4d, 5a, 5b, 5c, 8a, and 8b

Western sector of the Weaber Plain (CWW)

The dolomite outcrop that would be contained in Area CWW is an upland area that supports substrate-specific fauna, including reptiles (e.g. *Varanus acanthurus* and *Gehyra nana*) and mammals such as rock rat (*Zyzomys argurus*).

The two ephemeral billabongs adjacent to the dolomite outcrop (Figure 9.1) and created by irrigation water discharges from ORIA Stage 1 are waterbird and wader habitat, while the fringing vegetation supports additional bird species. The scheduled species radjah shelduck (*Tadorna radjah*) inhabits wetlands in this area.

Area CWW would also include Folly Rock (a place of cultural significance to Miriuwung and Gajerrong people) and an area around its periphery, including corridors linking Folly Rock to the north and south extremities of farmland on the Weaber Plain. Folly Rock supports upland site-specific flora and fauna, including *Brachyachne tenella*.

Soil Units conserved are 1, 2c, 4a, 4b, 4c, 4d, 5a, 5at, 5b, 5c, 6d, 8, 8a, 9a, 9b, 9c, and the Cockatoo Land System.

Eastern and Southern sector of the Weaber Plain (CWE)

Area CWE would include a seasonally inundated depression, including several small rock outcrops and an area of grassland and variable soils. The area would also include a large area of degraded Cockatoo Land System and a corridor to link that rock outcrop (a place of cultural significance to Miriuwung and Gajerrong people) with riparian vegetation of the Keep River.

The grassland areas that would be included in Area CWE also support black-soil endemics and the Western Australia threatened species yellow-rumped mannikin (*Lonchura flavipectus*). Peripheral zones would include Soil Unit 8a and habitat likely to be important for burrowing species. It may also support the Northern Territory threatened species, the zitting cisticola (*Cisticola juncidis*).

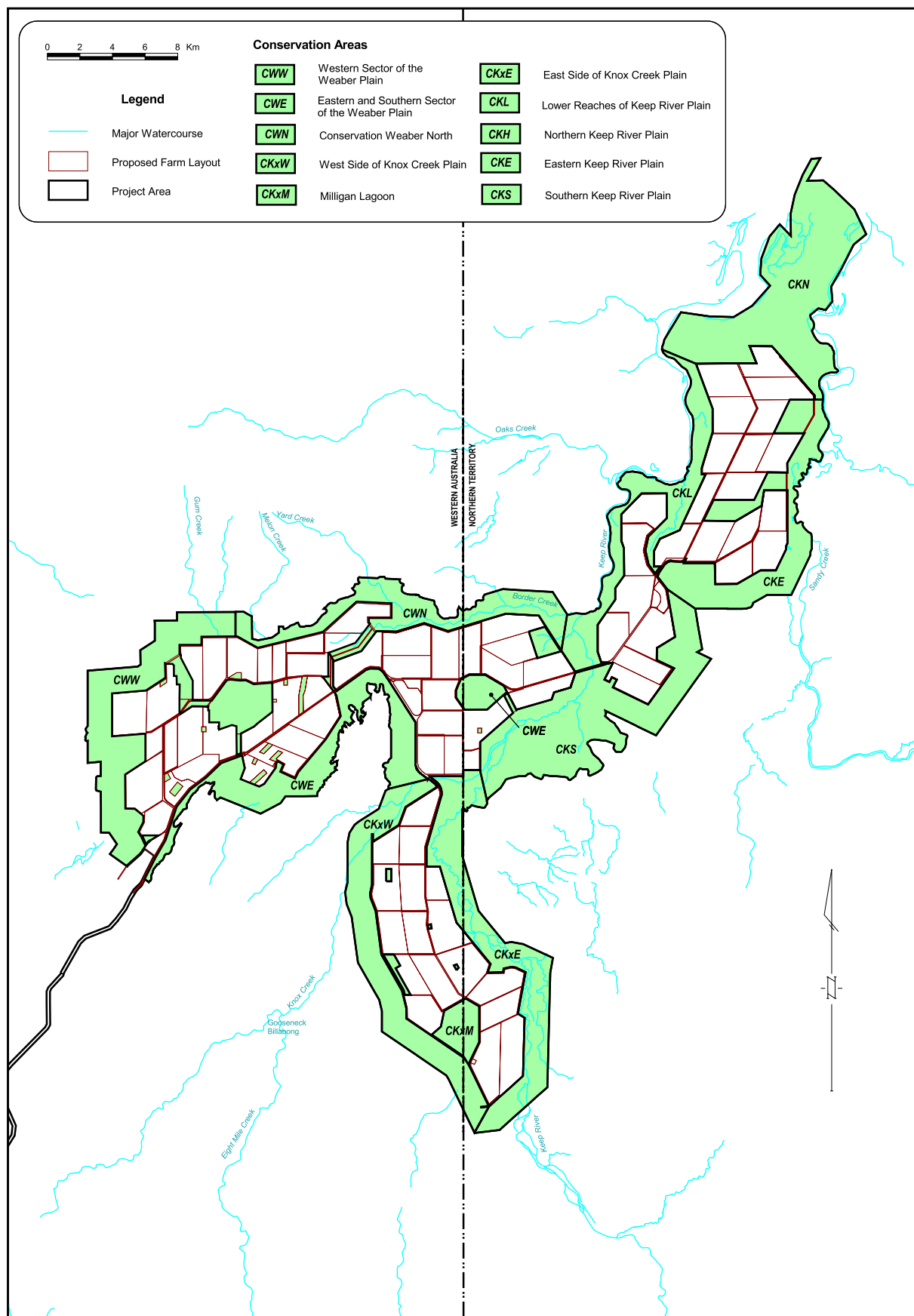


Figure 10.2 Conservation areas in the Project Area

Area CWE would include stands of wild rice (*Oryza australiensis*), which is a species restricted to the black-soil plains. The stands at this area are of exceptional size for Western Australia and, possibly, for the Northern Territory. Fantail grass (*Chrysopogon fallax*) occurs in association with *Oryza australiensis* in this area. *Echinochloa kimberleyensis*, a Priority 1 species in Western Australia, although sporadic in its distribution, also occurs in association with *Oryza australiensis* and *Chrysopogon fallax*.

This conservation area would include *Typhonium liliifolium* (3r flora species, Northern Territory) and *Lindernia tectanthera* (3r flora species, Northern Territory).

Soil Units conserved are 4a, 4c, 5a, 5b, 5bt, 5c, 6, 6a, 7b, 8a, and 8b.

Lower reaches of the Keep River (CKL)

Area CKL would include the dense riparian vegetation of the lower reaches of the Keep River, which is an important habitat for waterbirds and the threatened species white-browed robin (*Poecilodryas superciliosa cerviniventris*) and Gouldian finch (*Erythrura gouldiae*). The riparian vegetation in this area also supports a high diversity of reptiles, frogs and mammals, and is a habitat for freshwater crocodiles (*Crocodylus johnstoni*).

Purple-crowned fairy-wren (*Malurus coronatus coronatus*) (Schedule 1, Western Australia; Schedule 7, Northern Territory) has been found to occur in canegrass (*Sorghum* sp.) (Parks and Wildlife Commission of the Northern Territory 1998), a dominant grass species of Soil Unit 1, which is in this conservation area.

Area CKL is also considered to be an important feeding habitat for bats, with the dense vegetation providing protection. A number of plants would also be conserved here, including *Vittadinia spechtii* var. *kimberleyensis*, *Hygrophila angustifolia*, *Alysicarpus vaginalis* and *Fimbristylis macrantha*.

Soil Units conserved are 1, 2a, 2b, 2d, 3a, 4a, 4b, 4d, 5a, 7a, 7b, and 8.

Southern Keep River Plain (CKS)

Area CKS would include the largest section of Soil Unit 1 (black soil) to be conserved within the Project Area with vegetation representative of that of the Knox Creek and Weaber plains. It would include *Typhonium liliifolium* (3r flora species, Northern Territory), *Ipomoea* aff. *agrillicole* (3r flora species, Northern Territory) and *Fimbristylis laxiglumis* (Priority 3 flora species, Western Australia) as well as *Fimbristylis phaeoleuca*.

Purple-crowned fairy-wren (*Malurus coronatus coronatus*) (Schedule 1, Western Australia; Schedule 7, Northern Territory) has been found to occur in canegrass (*Sorghum* spp.). (Parks and Wildlife Commission of the Northern Territory 1998), a dominant grass species in Soil Unit 1, which is in this conservation area.

Area CKS would also include two areas of varied Soil Units 2a, 3a, 3c, 4b and 4c and combinations of these. Soil Unit 2a supports *Melaleuca minutifolia* woodland, which is considered by Connors et al. (1996) to be a poorly conserved fine scale vegetation type.

Soil Units conserved are 1, 4c, 4d, 5a, 5b, 5c, 6, and 7b.

Northern Keep River Plain (CKN)

Area CKN would include areas of the grasslands that are restricted within the Project Area to the northern area of the Keep River Plain, including areas of *Xerochloa* grasslands, a vegetation association regarded by Connors et al. (1996) as poorly reserved fine scale vegetation type.

The area would also include areas of *Halosarcia* mudflats, which do not occur elsewhere within the Project Area, *Cleome uncifera* (3r flora species, Northern Territory), *Tacca maculata* (3r flora species, Northern Territory) and *Triodia plectrachnoides*.

Soil Units conserved are 4a, 4d, 5a, 5b, 7a, and 7b.

Eastern Keep River Plain (CKE)

Area CKE would include *Schoenus punctatus* and poorly conserved vegetation community *Melaleuca minutifolia* woodland. It also conserves an area of mixed Soil Unit types, 1, 2a, 3a, 3c, 2c, and 4a.

Soil Units conserved are 1, 2a, 2b, 2c, 3a, 3a/3c, 3c, 3d, 4a, 4b, 4c, 4d, 5a, 5b, 5c, and 7a.

Milligan Lagoon (CKxM)

Area CKxM would include a large sandstone outcrop to the west of the lagoon. This entire area, including the sandstone outcrops and Milligan Lagoon, is of cultural significance to Miriuwung and Gajerrong people.

The different soils within this area support a varied plant life, from water plants (including waterlilies) and the sedgeland swamps on the edge of Milligan Lagoon to the *Terminalia canescens* woodland on the lower to middle slopes of the sandstone outcrop and *Eucalyptus miniata* woodland on the upper slope.

This conservation area would include *Brachychiton tuberculatus* (Priority 3 flora species, Western Australia; 3r species Northern Territory), *Echinochloa kimberleyensis* (Priority 1 flora species, Western Australia), and a newly recorded *Ficus* sp.

Grewia oxyphylla also occurs on a sandstone hill within Area CKxM.

Vegetation fringing the lagoon is recognised as an important habitat for waterbirds, reptiles and mammals. This vegetation supports waterbirds, migratory waders, and aquatic fauna (including an undescribed tortoise of the genus *Chelodina*), and it is a possible refuge for some terrestrial fauna such as the splendid tree-frog.

Area CKxM is also likely to be an important feeding area for bats, as the adjoining hills provide roosts for these animals.

The large sandstone outcrop adjoining the lagoon supports substrate-specific fauna.

Soil Units conserved are 1d, 6b, 8a, and 11b.

West side of the Knox Creek Plain (CKxW)

Area CKxW would include an area of *Astrebla squarrosa* vegetation, which has only been observed to date on the Knox Creek Plain (Ecologia Environmental Consultants 1997). *Astrebla squarrosa* - dominated vegetation is at its northern distribution limit on this plain.

The listed species *Triodia acutispicula* (Priority 3 flora species, Western Australia), *Brachychiton tuberculatus* (Priority 3 flora species, Western Australia; 3r flora species, Northern Territory), *Corchorus fascicularis* (3r flora species, Northern Territory), *Caesia chlorantha* (3r flora species, Northern Territory) and *Striga squamigera* (3r flora species, Northern Territory) also occur in this area.

The species *Eleocharis sunaica*, *Chamaecrista absus*, *Aphyllodium biarticulatum*, *Lophostemon grandiflorus* subsp. *grandiflorus*, *Lophostemon lactifluus*, *Goodenia malvina* and *Nesaea arnhemica* would also be conserved in this area.

Area CKxW would include the foothills of the Pincombe Range, an important habitat for many fauna species, especially reptiles. In addition, the caves and overhanging ledges are believed to provide important roosts for many species of bats.

Soil Units conserved are 1c, 1d, 1d/7f, 1f, 5e, 6e, 7f, 8, 8a, 11, and 11b.

East side of the Knox Creek Plain (CKxE)

Area CKxE would include riparian vegetation on both sides of the Keep River, and represents areas dominated by *Astrebla squarrosa*. It would also include *Enteropogon minutus*, a species not previously recorded for Western Australia.

Soils in the conservation area include Soil Units 1e and 7f, which are uncommon in the Project Area and have variable micro-habitats for a range of vertebrates and invertebrates.

Towards its southern extremity, area CKxE would be in close proximity to the Keep River National Park. This feature would enhance the conservation value of both areas. Area CKxE would include the species *Heliotropium foveolatum*.

Soil Units conserved are 1c, 1d, 1ds, 1e/7f, 1e, 1g, 5a, 6b, 7a/7b, 7b1, and 7f.

10.3.3 Protection of watercourses and rock outcrops

All rock outcrops and watercourses, including wetlands and billabongs with environmental and cultural significance, would be conserved. To maintain the effectiveness of these areas as fauna habitats, a system of corridors would provide links to adjacent areas of the surrounding Cockatoo Land System.

Vegetation would be maintained along all watercourses and wetlands. The width of these areas would be determined on a case-by-case basis, but as a minimum would be:

- 250 m from the incised channel of rivers
- 250 m from the outer edge of the riparian zone of natural wetlands
- 100 m from the incised channels of significant creeks.

It is envisaged that native title rights would prevail over all watercourses and rock outcrops within the Project Area.

10.3.4 Soil types

All the major soil types that occur in the Project Area would be represented within the conservation areas, although some of the minor soil types represented in small areas would not be protected (Table 10.5).

Table 10.5 Representation of each soil type in the development area and in the conservation area

Soil type	Development area (ha)	Conservation area	
		ha	%*
1	16699	5196	24%
1b	1	1	55%
1c	2191	609	22%
1d	3517	775	18%
1d/7f	144	31	17%
1ds	61	3	5%
1e	185	66	26%
1e/7f	11	54	84%
1f	198	74	27%
1g	700	71	9%
2a	256	151	37%
2a/3a	17	30	64%
2b	26	32	56%
2c	35	34	50%
2d	9	6	42%
3a	152	185	55%
3a/3c	16	12	43%
3b	41	0	0%
3c	77	84	52%
3d	32	10	24%
4	0	6	100%
4a	309	335	52%
4b	329	316	49%
4c	496	289	37%
4d	79	468	86%
4e	0	32	100%
5a	3372	1749	34%
5at	89	103	54%
5b	4062	698	15%
5bt	422	105	20%
5c	200	960	83%
5d	15	0	0%
5e	7	184	96%
6	3	200	99%
6a	0	8	100%
6b	1	372	100%
6d	1	120	99%
6e	12	148	92%
7a	96	3524	97%
7a/7b	18	605	97%
7b	31	615	95%
7b1	28	180	87%
7bs	0	20	98%
7f	401	173	30%
8	13	144	92%
8a	34	541	94%
8b	11	168	94%
9a	22	1	3%
9b	46	10	18%
9c	293	33	10%
11	49	692	93%
11b	0	50	100%
Other [†] (mainly rock)	14	20760	100%
Total	34818	41033	54%

* Indicates the percentage conserved of that particular Soil Unit in the whole of the Project Area (proposed development and conservation areas).

† Area not mapped by soil surveys.

Those soils not included in conservation areas are minor variants of the major soil types. For example, Soil Unit 1ds is the same as 1d but it has a stony surface; 3b and 3a are both red brown earths with solodic soil intergrades, Soil Units 9a, 9b and 9c have varying percentages of gradational calcareous clays in a matrix in land unit 1a; and 5d is a cracking clay with reduced internal drainage.

All rock outcrops, watercourses and natural, permanent water areas important for the conservation of flora and fauna would be included in the conservation areas. The cracking-clay black soil, which would be the focus of farm development, would have approximately 22% of Soil Unit 1 (1–1g inclusive) and approximately 32% of Soil Unit 5 (5a–5e inclusive) conserved.

10.3.5 Vegetation associations and flora

All undeveloped land within the Project Area would be managed for conservation. Most of this conservation area would be located around the perimeter of the Project Area, thereby providing an important physical link with the undeveloped areas of land outside the Project Area. In the Northern Territory this would include the proposed extension of the Keep River National Park and in Western Australia, the Point Spring Nature Reserve.

Four vegetation associations of the seventy-two described would not be conserved to some extent in the Project Area. However, the individual species present within each of these associations are represented in other vegetation associations within the conservation areas and the combined extent of these associations is only 133 ha, or 0.4% of the proposed development area (see Table 10.6).

Twelve vegetation associations only occur in the proposed conservation area and therefore would not be affected by development. Of the remaining fifty-six vegetation associations, only one would not have at least 10% represented in the conservation area.

Only one area included in the conservation area is isolated. This is the Cockatoo Land System on Spirit Hills Station. All other conservation areas connect from the perimeter conservation through wide corridors (at least 500 m) to the conservation areas along the Keep River or to another perimeter conservation area. This, together with management, should ensure the long-term viability of the included vegetation associations.

CALM is currently compiling a list of endangered vegetation communities for Western Australia (S. Claymore, Department of Conservation and Land Management, pers. comm., July 1999); however, such a list is not yet available for the Kimberley region. A. Mitchell, a botanist with the Ecologia (1997) survey, indicates that none of the associations within the black-soil plains are restricted (pers. comm., July 1999). The only association of restricted distribution in the Project Area is the *Echinochloa kimberleyensis* - dominated swamp near the foothills of the Weaber Range. This swamp would be included within the proposed conservation area and would be protected.

Table 10.6 Representation of vegetation associations in the development area and conservation areas (vegetation mapped area only)

Vegetation association	Development area (ha)	Conservation area (ha)	Percentage conserved (%)
Grassland			
G1	2459	924	27%
G2	190	276	59%
G3	0	12	100%
G4	1513	458	23%
G5	0	224	100%
G6	153	368	71%
Grassland with emergent trees			
Gt1	26	15	36%
Gt2	7210	1838	20%
Gt3	208	22	10%
Gt4	0	162	100%
Gt5	35	0	0%
Gt6	80	28	26%
Gt7	21	298	94%
Gt8	29	11	27%
Gt9	1	164	99%
Gt10	5	412	99%
Gt11	0	15	100%
Gt12	0	26	100%
Gt13	10	21	68%
Gt14	6	180	97%
<i>Bauhinia cunninghamii</i> woodland			
Bc1	11	37	77%
Bc2	246	178	42%
Bc3	6116	2136	26%
<i>Buchanania</i> woodland			
Bo1	21	174	89%
<i>Corymbia bella</i> woodland			
Cb1	0	32	100%
Cb2	180	273	60%
Cb3	7	81	92%
Cb4	1	220	99%
Cb5	418	170	29%
Cb6	123	71	37%
Cb7	619	390	39%
Cb8	26	146	85%
Cb9	26	9	27%
<i>Corymbia</i> sp., <i>Brachychiton diversifolius</i> and <i>Gyrocarpus americana</i> woodland			
CBG	5	52	91%
<i>Corymbia confertiflora</i> woodland			
Cc1	84	1	1%
Cc2	12	75	86%
Cc3	58	61	51%
Cc4	51	110	68%
<i>Corymbia tectifera</i> woodland			
Ct1	39	0	0%
Ct2	145	45	24%
<i>E. microtheca</i> woodland			
Em1	397	180	31%
Em2	135	62	31%
Em4	377	1090	74%
Em3	220	100	31%
Em5	0	39	100%
Em6	106	203	66%
Em7	176	22	11%
Em8	966	116	11%

Table 10.6 Representation of vegetation associations in the development area and conservation areas (continued)

Vegetation association	Development area (ha)	Conservation area (ha)	Percentage conserved
Em9	7026	2558	27%
<i>E. microtheca</i> and <i>Melaleuca</i> spp. woodland			
EM1	0	5	100%
EM2	275	1695	86%
<i>E. papuana</i> woodland			
Ep1	0	3	100%
<i>E. microtheca</i> woodland and shrubland of <i>Terminalia oblongata</i> ssp. <i>volucris</i>			
ET1	7	184	96%
ET2	103	67	39%
ET4	16	0	0%
ET5	350	97	22%
ET6	4326	2346	35%
<i>Excoecaria parvifolia</i> woodland			
Ex1	0	23	100%
Ex2	0	160	100%
Ex3	75	71	49%
Ex4	0	128	100%
<i>Melaleuca</i> sp. woodland			
Me1	5	36	88%
Me2	10	312	97%
Me3	43	0	0%
Me4	293	262	47%
<i>E. miniata</i> woodland			
Min1	1	383	100%
Min2	9	1302	99%
<i>Terminalia canescens</i> woodland			
Tc1	2	38	96%
<i>Eucalyptus microtheca</i> and <i>Melaleuca</i> spp. woodland			
EM1	1	12	92%
EM2	21	107	84%
EM3	55	1595	97%
<i>Eucalyptus tetradonta</i> woodland	9	89	91%

No threatened communities covered by the *Endangered Species Protection Act 1992* occur in the Project Area.

One plant species of conservation significance—the tentatively named *Sorghum grande*, which was collected during the Ecologia fieldwork—is not known to be included within the proposed conservation areas. Additional collections of this plant would be required to confirm the species' identity and, if the identification were positive, to determine its distribution. It was not recorded during Kinhill's 1999 survey.

Rare and priority species identified within the Project Area and the relevant conservation area are detailed in Table 10.7.

Table 10.7 Representation of rare and priority species within conservation areas within the Project Area

Rare and priority species	Classification and State or Territory	Location in proposed conservation areas									
		CWN	CWW	CWE	CKL	CKS	CKN	CKE	CKxM	CKxW	CKxE
<i>Atalaya salicifolia</i>	3r (NT)	✓									
<i>Brachychiton tuberculatus</i>	P3 (WA), 3r (NT)								✓	✓	
<i>Caesia chlorantha</i>	3r (NT)									✓	
<i>Cleome uncifera</i>	3r (NT)						✓				
<i>Corchorus fascicularis</i>	3r (NT)		✓							✓	
<i>Echinochloa kimberleyensis</i>	P1 (WA)	✓							✓		
<i>Fimbristylis laxiglumis</i>	P2 (WA), 3r (NT)					✓					
<i>Ipomoea aff. agrillicola</i>	3r (NT)					✓					
<i>Lindernia tectanthera</i>	3r (NT)			✓							
<i>Sorghum grande</i>	3r (NT)				Not confirmed in conservation area						
<i>Striga squamigera</i>	3k (NT)									✓	
<i>Tacca maculata</i>	3r (NT)						✓				
<i>Triodia acutispicula</i>	P3 (WA)									✓	
<i>Typhonium liliifolium</i>	3r (NT)			✓		✓					
<i>Vittadinia spechtii</i> var. <i>kimberleyensis</i>	3r (NT)				✓						

10.3.6 Native fauna and associated habitats

All the fauna habitats identified by Ecologia (1997) would be represented in the proposed conservation areas within the Project Area. Ecologia separated woodlands into eucalypt and bauhinia woodlands. Kinhill's 1999 survey (Appendix J) concluded there were no significant differences between these habitats; hence they have been combined as 'woodland'. Those considered to include site-specific species would have the majority of their habitat area conserved, as indicated in Table 10.8.

The proposed development would occur in the woodland and grassland fauna habitats. Development would result in the large-scale removal of grass species, trees and shrubs. The grass species are commonly utilised by many fauna species for seed, while the trees and shrubs provide nectar and insect food. It is also expected that some of the fauna in the areas adjacent to the proposed development area would utilise the development area for food and shelter. While the food source would be reduced, it should be noted that the grasses are common throughout the eastern Kimberley region, and it is anticipated that many fauna species would forage in the proposed conservation areas.

Table 10.8 Representation of fauna habitats in the development area and conservation areas (see Section 8.2)

Fauna habitat	Development area (%)	Conservation area (%)
Grassland	55	45
Woodland	58	42
Riverine woodland	1	99
Vine thicket	0	100
Wetland*	10	90
Rock outcrop	0	100

* Includes the man-made wetland on the Weaber Plain.

All rare and specially protected fauna identified within the Project Area would have their usual habitat retained (Table 10.9). As the rivers, creeks, lagoons, temporary creeks, and pools are included in the proposed conservation areas the fish species recorded by Larson (1999) (Appendix L) from the Keep River and Sandy Creek would not be directly affected by development. Of the sixteen mollusc species recorded by Wilson and Stoddard (1979), five were located only in temporary creeks and pools, several of which would be conserved. None should be impacted as these habitats are included in the conservation areas.

Table 10.9 lists the preferred habitat of all rare and protected fauna known to occur in the Project Area.

Table 10.9 Preferred habitat of rare and specially protected fauna

Species name	Common name	Habitat preference	Area conserved (%)
Mammals			
<i>Macroderma gigas</i>	Ghost bat	W, GR, RW, WE, RO, VT	51
<i>Hipposideros stenotis</i>	Wart-nosed horseshoe-bat	GR, RW, WE, VT	79
<i>Hydromys chrysogaster</i>	Water rat	W, GR	43
<i>Leggadina lakedownensis</i>	Lakeland Downs mouse	W, GR	4
<i>Phascogale tapoatafa</i>	Brush-tailed phascogale	W, GR, RW	48
<i>Sminthopsis butleri</i>	Butlers dunnart	W, GR	43
Birds			
<i>Accipiter novaehollandiae</i>	Grey goshawk	VT	100
<i>Apus pacificus</i>	Fork-tailed swift	RW, VT	99
<i>Ardea sumatrana</i>	Great-billed heron	RW, WE	99
<i>Ardeola alba</i>	Great egret	RW, DW, W	48
<i>Ardeola ibis</i>	Cattle egret	RW, WE	99
<i>Aviceda subcristata</i>	Pacific baza	W, GR, RW, WE, RO	51
<i>Burhinus grallarius</i>	Bush stone-curlew	W, GR, RW, WE	48
<i>Calidris ruficollis</i>	Red-necked stint	RW, WE	99
<i>Calidris subminuta</i>	Long-toed stint	RW, WE	100
<i>Cisticola juncidis</i>	Zitting cisticola	W, GR, RW, WE	48
<i>Cuculus saturatus</i>	Oriental cuckoo	W, GR, RW, WE	48
<i>Esacus magnirostris</i>	Beach stone-curlew	W, GR, RW, WE	48
<i>Erythrotriorchis radiatus</i>	Red goshawk	W, GR, RW, RO	51
<i>Erythrura gouldiae</i>	Gouldian finch	RW, WE	99
<i>Eurostopodus argus</i>	Spotted nightjar	RO, VT	100
<i>Falco hypoleucos</i>	Grey falcon	W, GR, RO	47
<i>Falco peregrinus</i>	Peregrine falcon	WE, RO	100
<i>Falcunculus frontatus whitei</i>	Kimberley crested shrike-tit	W, RW, VT	48
<i>Geophaps smithii blaaui</i>	Partridge pigeon	W, GR, RO	47
<i>Haliaeetus leucogaster</i>	White-bellied sea-eagle	RW, WE	99
<i>Hamirostra melanosternon</i>	Black-breasted buzzard	W, GR, RW, WE, RO	51
<i>Ixobrychus flavicollis gouldi</i>	Black bittern	RW, WE, RO, VT	99
<i>Lonchura flaviprymna</i>	Yellow-rumped mannikin	W, GR, RW, WE	48
<i>Lophoictinia isura</i>	Square-tailed kite	W, GR, RW, RO	51
<i>Malurus coronatus coronatus</i>	Purple-crowned fairy-wren	RW, VT	99
<i>Megapodius reinwardt</i>	Orange-footed scrubfowl	RW, VT	99
<i>Merops ornatus</i>	Rainbow bee-eater	W, GR, RW, WE, RO, VT	51
<i>Microeca flavigaster tormenti</i>	Lemon-breasted flycatcher	W, GR, RW	48
<i>Neochmia ruficauda</i>	Star finch	W, GR, RW, WE, VT	49
<i>Ninox rufa rufa</i>	Rufous owl	W, RW, VT	48

Table 10.9 Preferred habitat of rare and specially protected fauna (continued)

Species name	Common name	Habitat preference	Area conserved (%)
<i>Plegadis falcinellus</i>	Glossy ibis	RW, WE	99
<i>Poecilodryas superciliosa cerviniventris</i>	Derby white-browed robin	VT	100
<i>Rostratula benghalensis</i>	Painted snipe	WE	90
<i>Tadorna radjah</i>	Radjah shelduck	VT, WE	90
<i>Tringa brevipes</i>	Grey-tailed tattler	RW, WE	99
<i>Tringa glareola</i>	Wood sandpiper	RW, WE	99
<i>Tringa hypoleucos</i>	Common sandpiper	RW, WE	99
<i>Tringa nebularia</i>	Greenshank	RW, WE	99
<i>Tringa stagnatilis</i>	Marsh sandpiper	RW, WE	99
<i>Turnix castanota</i>	Chestnut-backed button-quail	W, GR, RO	47
<i>Tyto novaehollandiae</i>	Masked owl	W, VT	42
Reptiles			
<i>Crocodylus johnstoni</i>	Freshwater crocodile	RW, WE	99
<i>Crocodylus porosus</i>	Saltwater crocodile	RW	99
<i>Varanus glauerti</i>	Glauert's monitor	RO	100
<i>Varanus kingorum</i>	Long-tailed pygmy goanna	RO	100
Amphibians			
<i>Cyclorana vagitus</i>	Wailing frog	W, GR	43
<i>Litoria splendida</i>	Splendid tree-frog	WE, VT	90

W = woodland; GR = grassland; RW = riverine woodland; WE = wetlands; RO = rock outcrops; VT = vine thicket.

Source: Kinhill Pty Ltd (1999), Ecologia (1997).

10.3.7 Comparison with other conservation proposals

Ecologia (1997) made recommendations for conservation areas as part of a previous proposal to develop the Project Area for the purposes of irrigated agriculture. The Ecologia recommendations were reviewed by Woinarski and Connors (1997), whose analysis considered plant and terrestrial vertebrate species attributes and terrestrial environments as described by soil mapping. The analysis included an assessment of the occurrence and preservation requirements of plant and animal species in the Project Area vis-à-vis the surrounding region by examining whether any of the relevant species were prevalent in existing reserves elsewhere in the Northern Territory or the Kimberley region. Woinarski and Connors (1997) also considered three alternative conservation scenarios to that proposed by Ecologia, each with differing conservation targets, including representation of soil types and plant and animal species deemed to be of conservation significance. The conclusions were as follows:

- The Ecologia (1997) recommendations were comprehensive and provided a good representation of the broad soil types present in the Project Area, and a fair representation (approximately 50%) of the plant and animal species deemed to be of conservation significance.
- The least frugal of the Woinarski and Connors scenarios (known as Scenario 3) required 100 km² to represent all soil types by at least 5% of their extent in the Project Area, and to represent all thirty-five plant species and animal species considered to require conservation.

- The proposed Scenario 3 was superior (in terms of less land required for conservation and greater representation of target attributes), but there was reasonable correlation with the Ecologia (1997) recommendations.

The Woinarski and Connors (1997) Scenario 3 design is shown in Figure 10.3 as an overlay to the current schematic layout of the Project Area. The current conservation strategy for the proposed development includes a greater proportion of black-soil plain in conservation areas, by virtue of the conservation area on the southern Keep River Plain. Woinarski and Connors (1997) suggested individual farm units of black-soil plains be conserved. However, greater representation of this soil type has been achieved by conserving a large area of black-soil plain in the southern Keep River Plain. The conservation of one large area rather than several smaller areas ensures greater integrity of the vegetation and fauna habitats.

Variations in soil types, particularly on the Keep River Plain, have been conserved in both proposals. Similarly a corridor connecting the northern perimeter conservation area via the dolomite hill to Folly Rock and through the southern perimeter conservation area in the Weaber Plain is a feature of both proposals.

Woinarski and Connors (1997) noted that all of their target levels (at least 5% of either broad or fine soil types represented in protected areas) were frugal in comparison to those generally accepted in land planning. For example, the Comprehensive Regional Assessment process flowing from the National Forest Policy Statement sets representation targets of 5–15% of all ecosystems mapped at a scale of 1:100,000, and more adequate representation of threatened species (Anon. 1996).

The issue of satisfying industry targets for adequate representation of ecosystems has been addressed as part of the proposed conservation strategy through dedication of a larger proportion of the black-soil plains in the Project Area to conservation than was proposed by Woinarski and Connors (1997). Table 10.5 shows that 25% of the black-soil plains (Soil Units 1 and 5) within the Project Area would be conserved.

10.4 ASSESSMENT OF POTENTIAL IMPACTS

This section identifies the potential environmental impacts associated with the development and operation of the proposed development, and the predicted level of impact of each. Also, the proposed management measures to mitigate impacts are described in Section 10.5. The proposed development would take place predominately on the black-soil plains. These cracking clays are typically dominated by savanna woodland, a homogeneous habitat consisting of baubinia woodland, eucalypt woodland and grassland.

10.4.1 Mammals

As with any sizeable land development, it is inevitable that individuals of some of the smaller species of mammals may be detrimentally affected during construction activities. Some may move, and survive, within the proposed conservation areas. Other individuals may be displaced and may later succumb to predators, stress or territorial conflicts during attempts to re-establish a home range. However, none would become locally extinct.

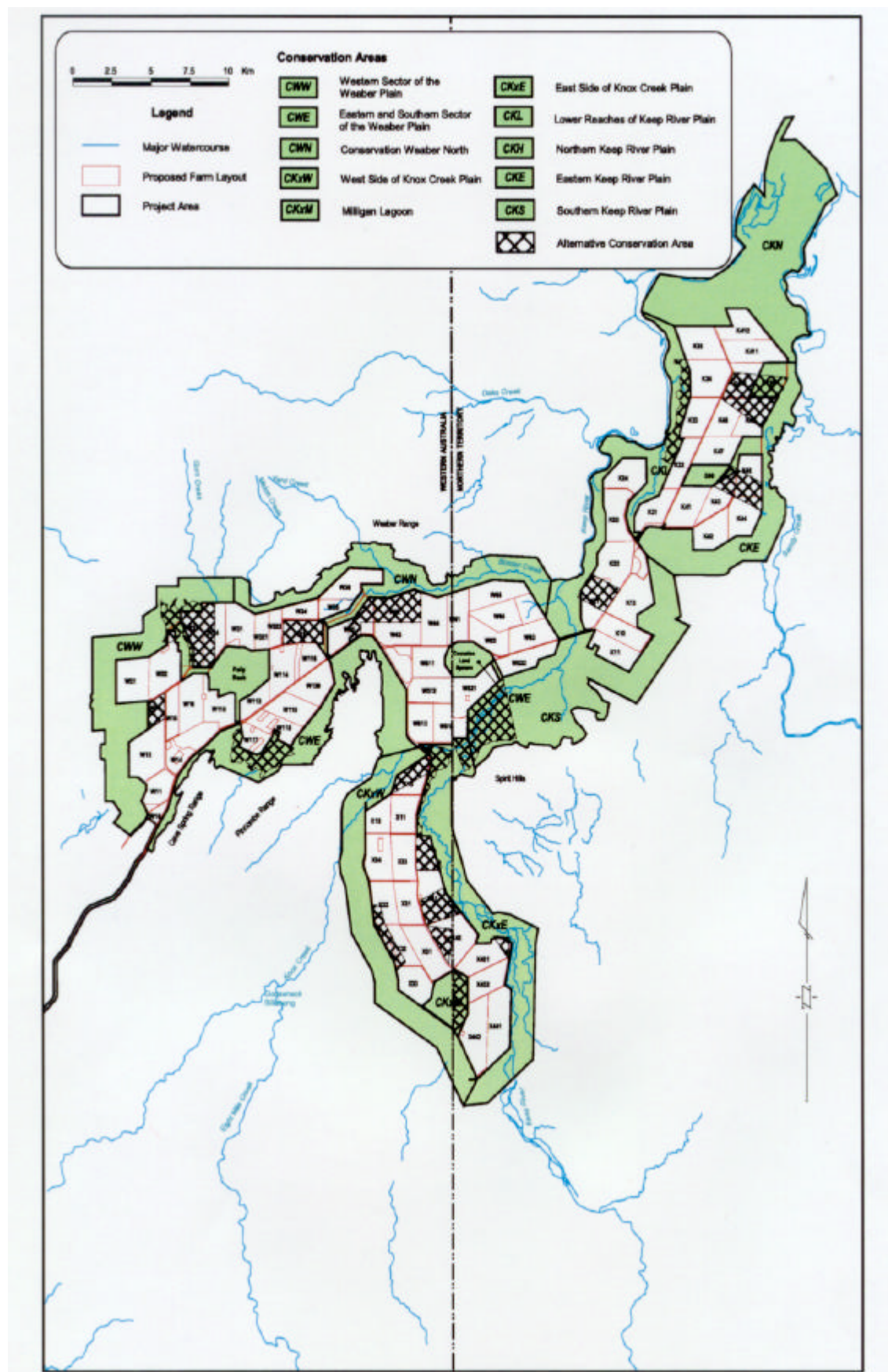


Figure 10.3 The Scenario 3 design of Woinarski and Connors (1997)

Clearing of the black soil vegetation would reduce the foraging habitat for some terrestrial (arboreal) species and some bats, as well as remove some den and roost trees. However, the areas of natural vegetation preserved on the hills and along watercourses within the conservation areas would minimise this particular impact. Data obtained during the most recent fauna survey (Kinhill Pty Ltd 1999) indicated that there was a lower diversity and abundance of bats foraging on black-soil plains than along the watercourses and rock outcrops.

Ghost bats roost during the day in large caves or abandoned mines and range widely at night. These animals would not be adversely affected by the proposed development because their preferred roosting habitat would not be disturbed. However, sufficient areas of its habitat are included in the conservation area to ensure the species survival. Three species of mammals, Water rat, Lakeland Downs mouse and Buttlers dunnat are restricted to the woodland or grassland habitat (Appendix J). At these are the vegetation associations proposed for development, and the impact of development on some of these animals will be great. However the species will continue to survive in the conservation areas and may even adapt to the tall grassland of the sugar canefields.

10.4.2 Birds

Nesting sites and foraging areas for birds may unavoidably be affected during construction activities, but it is envisaged that most individuals would be able to move into the adjoining conservation areas. In ORIA Stage 1, some birds—including brolgas, magpie geese, radjah shelduck, parrots and finches—have benefited from the development of irrigated farms.

Yellow-rumped mannikins are known to prefer areas of permanent water with fringing vegetation. It is unlikely that the population of this species would be reduced since all natural wetlands and rivers would be included in the conservation areas.

Derby white-browed robins inhabit vine thickets and woodlands associated with river systems. The species should not be adversely affected by the proposed development because its habitat would be conserved and adjacent areas.

The Gouldian finch was not recorded during surveys by Ecologia or Kinhill, but has been recorded from near Kununurra (NSR 1992). The preferred habitat for this species is eucalypt woodland with a grass understorey of *Sorghum* spp. However, they have been known to move out of these habitats during the wet season, to return when the *Sorghum* spp. begin to release seed.

The Gouldian finch is known to nest mainly in the hollows of trees, with occasional reports of nests in termite mounds, low bushes, spinifex or tall grasses. Studies in the Northern Territory have recorded Gouldian finch nests in *Eucalyptus brevifolia*, *E. leucophloia*, *E. tintinnans* and *E. miniata*, only the latter being recorded from the Project Area. However, as all areas of *E. miniata* in the Project Area are included in the conservation areas, the preferred nesting habitat of this species would not be impacted.

Red goshawk was not recorded during the Ecologia 1997 survey or the Kinhill 1999 survey, but it may be present in the Project Area. The impact that the proposed development would have on this species (if present) is unknown.

10.4.3 Reptiles

Some individuals may relocate to adjoining conservation areas, but some may unavoidably be killed during construction activities. Based on existing information for ORIA Stage 1, most of the reptile species would survive and it is considered likely that some may benefit from the establishment of the irrigation system.

10.4.4 Frogs

It is anticipated that most, if not all, species of frogs native to the Project Area would continue to live and thrive in the irrigated areas, as has occurred in ORIA Stage 1. Those with specialist habitat niches—such as Copland’s rock frog, which is restricted to the rock outcrops—would not be affected by the proposed development. The wailing frog is the only species restricted to woodlands or grasslands, but this species should continue to survive in the conservation areas and adapt to the development.

It is of interest to note that the flat-headed frog (*Limnodynastes depressus*), which had been thought to be extinct, has recently been recorded at Cockatoo Lagoon in the Keep River National Park and at Lissadell Station in Western Australia. This frog is endemic to the Ord River catchment and is apparently a naturally rare species. Its close relative *L. tasmaniensis*, which occurs naturally in southern Australia, was accidentally introduced to the Ord River catchment a number of years ago and is now widespread in irrigated areas; it was, for example, recorded by Kinhill in the Project Area in June 1999. Adults of the two species are virtually indistinguishable. The possibility that the very rare *L. depressus* could also exist in the Project Area should not be discounted and if it should be recorded, the information would be provided either to CALM or the Parks and Wildlife Commission of the Northern Territory.

10.4.5 Fish and aquatic biota

The proposed conservation areas would include all significant waterways, billabongs and wetlands, and their associated riparian vegetation. Direct impacts upon the habitats of fish and other aquatic biota would therefore be avoided, except in two localised areas associated with the road crossings of the Keep River and Knox Creek.

It is envisaged that insecticides would not be used on sugarcane grown in the Project Area, consistent with current practice in ORIA Stage 1 (see Table 2.1). Furthermore, only minimal volumes of herbicides would be used in the canefields. Herbicide would only be applied to the sugarcane once per year, in the period following harvesting. The tailwater return systems proposed for use on all farms within the Project Area have been designed to collect on-farm herbicide runoff, and to avoid any such runoff into the adjacent aquatic environment (see Chapter 5).

Chapter 5 describes the predicted changes to the hydrology of the Keep River and Sandy Creek from proposed development. These changes would be contained to the lower reaches of these watercourses and would involve:

- an insignificant change in water quality due to the combined effect of proposed management measures for the use of farm chemicals and on-farm water management;
- a minor increase in peak flood velocities and an increase in the occurrence of peak flood levels due to the construction of flood protection levees;

- an increase in average flows during the wet season, and infrequent and minor releases of good quality water during the dry season.

These predicted changes are not expected to result in any significant impacts on fish and other aquatic biota in the Keep River and Sandy Creek. The altered flow regime may cause some localised erosion, but this should stabilise with time. The differential effect of the increased average flows would be greater in drier years and, at these times, the additional flows that would occur earlier and later in the wet season would benefit an environment that would otherwise be under stress.

The groundwater management strategy that would be adopted for the Project involves the recovery of groundwater from strategically located bores in the Project Area. Disposal of the collected groundwater would be either by reuse (subject to quality) as irrigation water, or by pumping to the tidal portions of the Keep River and Sandy Creek, as shown in Figure 6.1. The salinity of the water requiring disposal to the Keep River and Sandy Creek is predicted to be in the range 2,200–20,000 mg/L TDS. Except for times of high flow in these watercourses, the receiving water would be marine, with a salinity of about 35,000 mg/L TDS.

The main issues associated with the discharge of the collected groundwater are the potential effects on water quality and marine fauna due to:

- the slightly elevated levels of total nitrates, predicted to be in the range of 3.1–5.2 mg/L;
- the altered hydrology with respect to continuous discharges of lower salinity water with respect to the receiving water;
- the possibility of elevated levels of insecticides, herbicides and phosphorus, although experience with ORIA Stage 1 would indicate that the risk of these being significantly elevated is remote.

The primary means of managing these potential impacts would be via the selection of the discharge locations. It is anticipated that a period of approximately ten years would be available following the commencement of cropping before discharges might become necessary. This period would be used by the Environmental Management Entity that would be established as part of the Project (see Chapter 16) to undertake further studies aimed at:

- improving the predictions of the quality of the groundwater requiring disposal;
- confirming the adequacy of the discharge locations, or selecting alternative sites in consultation with the DLPE.

The tidal range at the mouth of the Keep River and Sandy Creek is approximately eight metres, providing conditions of swift moving, naturally highly turbid waters. Such conditions would be suitable for dilution and assimilation of any saline discharge, and would diminish the possibility of excessive algal growth that could be caused by elevated nitrate levels. There is a high degree of confidence that the strategy outlined above can be implemented with negligible impacts upon water quality and aquatic fauna.

10.4.6 Insects

It is not envisaged that insecticide would be applied to sugarcane grown in the Project Area. However, as the development of the Project Area will result in the removal of natural vegetation from the areas earmarked for farming, those native insect species living in these

areas which have very specific food and shelter requirements would certainly be impacted. It is nevertheless anticipated that the conservation areas to be laid aside would provide adequate resources for all these species to survive within and around the Project Area.

10.4.7 Stygofauna

The sampling that has been undertaken to date has indicated the presence of one species of stygofauna in groundwater in the western portion of the Weaber Plain. The same species was also recorded from the groundwater beneath ORIA Stage 1.

The eastern portion of the Weaber Plain, the Keep River Plain and the Knox Creek Plain are underlain by a palaeochannel similar to the western portion of the Weaber Plain. Hence, sampling in these areas is also likely to indicate the presence of stygofauna.

Chapter 6 describes the predicted changes to the groundwater environment of the Project Area due to the proposed development. In general, these predicted changes would include a rise in groundwater levels; existing habitats would therefore remain flooded, and only minor changes in water quality would result. In particular, that there has been no significant changes to groundwater quality beneath ORIA Stage 1, which has been used for irrigated agriculture for over thirty years, would support this conclusion.

10.4.8 Interbasin water transfers

The proposed development of the Project Area would result in the transfer of water, via the irrigation water distribution system, from the Ord River basin into the Keep River basin. Potential therefore exists for the transfer of aquatic invertebrates or other biota, via the irrigation water, from the Ord River to the Keep River. However, the risk that the inter-basin transfer of water would result in a change to the ecology of the Keep River is expected to be minimal and would be mitigated by the following factors:

- The Keep River is no longer pristine with respect to inter-basin transfers, as such transfers have been occurring for over 30 years since the establishment of ORIA Stage 1. Water level control in the M1 Channel is currently maintained by allowing continuous discharges, via a drain, on to the Weaber Plain. During the wet season these discharges would have uncontrolled access to the Keep River.
- Project development would include a range of measures designed to eliminate, during normal operations, discharges of irrigation water to the Keep River. These measures are detailed in Chapter 5 and include:
 - the provision of irrigation tailwater return systems to all farms in the Project Area;
 - the establishment of regulating storage dams along the route of the M2 Channel that would provide operational storage, which would obviate the need for discharge of irrigation water to watercourses in the Keep River basin;
 - computer-controlled operation of control structures along the M2 Channel, which would optimise the efficiency of water delivery throughout the Project Area.

10.4.9 Recovery plans for threatened species

Both the Parks and Wildlife Commission of the Northern Territory and CALM have recovery plans for fauna and flora species. The recovery plan for the Gouldian finch is the only such plan applicable to the proposed development.

As detailed in Section 10.4.2, the Gouldian finch may be disadvantaged by land-clearing associated with the proposed development. However, it would appear the preferred nesting habitat of this species would not be impacted. A requirement of the recovery plan is that any sightings of Gouldian finches feeding or breeding should be reported to one of the above departments.

10.4.10 Existing conservation reserves

The Keep River National Park is approximately 6 km south of the Project Area. Being upstream of the Project Area, it is unlikely that the Keep River National Park would suffer any significant direct detrimental impact as a result of the proposed development. However, indirect potential impacts could be caused by the introduction and spread of weeds and feral animals, and an increase in the number of visitors to the park.

Point Spring Nature Reserve, less than 1 km north of the Weaber Plain portion of the Project Area, protects a permanent spring, remnant rainforest and a small wetland at the base of the Weaber Range. The Point Spring Nature Reserve is a Class A reserve for the conservation of flora and fauna. This reserve includes small areas of black soil and sandy alluvium. Point Spring is in a groundwater system separate from the adjacent alluvial plains and, as a consequence, would be isolated from any changes in the water-table in the Project Area. However, its close proximity to the Project Area has necessitated the implementation of special management and design considerations, with particular reference to anticipated higher flood water levels and flow velocities. A buffer has been incorporated into the design of the proposed development to insulate Point Spring Nature Reserve from these effects.

To ensure that the existing environmental significance of the Point Spring Nature Reserve is maintained, Wesfarmers–Marubeni and the Water Corporation would cooperate with CALM in implementing its management requirements for the site. The overall responsibility for the management of the reserve would remain with CALM. The conservation area between the proposed farmland and Point Spring Nature Reserve would be managed for the purpose of conservation.

All other conservation reserves in the region are removed by over 100 km from the Project Area and are unlikely to be affected by the proposed development.

10.4.11 National Wilderness

The Commonwealth Government initiated the National Wilderness Inventory (NWI) in 1986 in response to community concerns about the diminishing extent of remote and natural lands in Australia. The NWI is administered by the World Heritage and Wilderness Branch of Environment Australia. The Branch defines wilderness as:

...land that, together with its plant and animal communities, is in a state that has not been substantially modified, and is remote from, the influences of European settlement or is capable of being restored to such a state, is of sufficient size to make its maintenance in such a state feasible, and is capable of providing opportunities for solitude and self-reliant recreation.

Wilderness values, measured on a continuum from 0 to 20, are developed in consideration of remoteness from settlement, remoteness from access, apparent naturalness (lack of permanent structures), and biophysical naturalness (degree of biophysical disturbance such as grazing, logging, mining etc.).

The Keep River Plain and the Knox Creek Plain have been assigned low Wilderness Quality ratings, mostly between 1 and 9, but sections of the Weaber Plain include areas with ratings of 14 or higher.

The areas surrounding the Project Area are rated with scores above 12. These areas would be included in the conservation areas and, with the removal of cattle and the implementation of active management practices, it is expected that some areas would improve in quality, resulting in a higher rating for Wilderness Quality. Cattle have severely degraded a significant portion of the Project Area by grazing and trampling the vegetation.

10.4.12 Combined and cumulative impacts

In this ERMP/draft EIS the following definitions are used:

- ‘Combined effect’ refers to the impact on the local area and region due to construction and operation of the proposed development, other ORIA Stage 2 developments and existing ORIA Stage 1 activities;
- ‘Cumulative effect’ refers to the accumulation of effects over time, whether associated with the proposed development alone or in combination with other projects.

The cumulative effects associated with the proposed development relate to groundwater management issues which are addressed in Chapter 6, issues related to greenhouse gas emissions which are addressed in Chapter 13, and landscape ecology which will be addressed through the proposed monitoring programme.

There is currently only limited information available on the other ORIA Stage 2 development projects. Therefore, the comments provided below are only indicative of the possible outcomes of a more thorough combined effects assessment that would be possible only when details of proposed developments are published.

The potential issues include:

- effects of additional use of water from the Ord River for irrigated agriculture;
- regional vegetation clearance effects on plant species and associations and fauna habitats and therefore, on populations of fauna species.

Section 5.2 of this ERMP/draft EIS describes the process being adopted by the Water and Rivers Commission to address the combined effects of the Project and other developments on the ecology and other values of the lower Ord River. This process has commenced with the preparation by the Commission of the draft interim Water Allocation Plan for the Ord River and publication of this plan for public comment and advice of the EPA. Wesfarmers–Marubeni and the Water Corporation have assumed that the final (long-term) water allocation to the Project will be consistent with the interim allocations currently proposed by the Water and Rivers Commission.

Ecologia were commissioned in 1996 by the Department of Resources Development to undertake biological surveys of all the ORIA Stage 2 development areas, including the

Project Area and land suitable for horticultural development of the Riverside Development Areas of the Mantinea Flats, Carlton Plain and the Ord River West Bank area. A comparison of the results of these surveys, provided in Appendix K, shows that while there is a significant overlap between the floristic composition of this sites, the data analysis clearly separates the Project Area from the Riverside Development Areas. The strategy of conserving representative and reasonably sized viable portions of vegetation associations and fauna habitats in the Project Area should therefore be an effective means of mitigating combined regional vegetation clearance effects.

10.5 ENVIRONMENTAL MANAGEMENT

An Environmental Management Plan (EMP) would be prepared prior to development to guide and mitigate any potential environmental impact associated with the proposed development. The EMP would consider both construction and operational activities. An outline of the EMP is discussed in Section 16.5 and presented in Appendix O.

10.5.1 Vegetation associations and fauna habitats

To limit any potential for overclearing, all areas designated for construction works would be clearly marked on development maps and on the ground prior to commencement of works. Vegetation clearance would be staged so that areas are cleared only as required.

In Western Australia a 'Notice of Intention to Clear Land' would be issued to the Commissioner of Soil Conservation, in accordance with the requirements of the *Soil and Land Conservation Act 1945*. In the Northern Territory, an application would be made to the Department of Lands, Planning and Environment to clear land.

Designated conservation areas and vegetation buffers would be clearly established and monitored to ensure they remained undisturbed.

All contractors and consultants would be required to participate in a formal environmental and cultural heritage induction programme on the importance of the natural and social environment.

In Western Australia, an application would be lodged for permission from CALM, under the *Wildlife Conservation Act 1950*, to take Priority flora.

In the Northern Territory an application would be lodged with the Minister for Parks and Wildlife seeking permission to 'take' Specially Protected plants. Another application would be lodged with the Director, Parks and Wildlife for a non-commercial permit to take Protected Flora.

If seeds are collected for rehabilitation within the Project Area, an application would be made to CALM and the Parks and Wildlife Commission of the Northern Territory for a permit for each person undertaking the collection.

10.5.2 Fire

A fire control strategy and plan would be developed for the farms and for the proposed conservation areas. This would include monitoring areas to determine the need for burning.

There is evidence to show that ‘fire stick farming’ was utilised widely by Aboriginal people prior to the European colonisation, and the practice continues across northern Australia. Typically, much of northern Australia has been burnt during the dry season, resulting in changes to the structure and composition of vegetation communities, including degradation of vine thickets and increased frequency of weeds (Government of Western Australia 1997a, b & c).

The preferred season for burning is the end of the wet season when the fires would be less severe (G. Graham, Department of Conservation and Land Management, Kununurra, pers.com., August 1999). This would clear the debris without harming the bushland.

Advice would be sought from CALM and the Parks and Wildlife Commission of the Northern Territory in the preparation of a Fire Management Plan for the Project Area, including the proposed conservation areas. This plan would take into account community assets, environmental values, fire frequency and season, and the impact that fire could have on human life (e.g. those at risk due to fire).

The Environmental Management Entity (see Chapter 16) would apply for membership of the Bushfires Council (Northern Territory).

10.5.3 Weeds

Various mechanisms would be used to control the introduction of weeds to the Project Area. Mandatory interstate quarantine would be maintained to control weeds from other areas. During construction, all construction machinery would be cleaned of soil and other organic debris prior to being transported to the Project Area.

Once construction and development works are complete, each farmer would be responsible for the recognition and control of weeds on their property. The Environmental Management Entity would oversee the environmental management of the Project Area, including the identification of weeds in the Project Area, and provision of advice and assistance about control/eradication.

Acrolein has successfully been used for the control of aquatic weeds in ORIA Stage 1 for many years. Continued use of acrolein is currently subject to an Australia-wide review. Emergent vegetation such as Cumbungi would be restricted and controlled by the use of glyphosate-based herbicide applications (using formulations modified to reduce impact on frogs and other aquatic fauna), as well as mechanical control measures. Effective control of Cumbungi from the time of construction would limit the extent of any ongoing control programme.

If any Declared Weeds or new plants/weeds were introduced into the Project Area, the Weed Science Section of AGWEST, or the Department of Primary Industries and Fisheries (Northern Territory) would be consulted to ensure compliance with relevant legislation and to ensure implementation of appropriate control measures.

The Environmental Weed Strategy for Western Australia (Department of Conservation and Land Management, 1999) lists the environmental invasiveness and impacts of weeds in the Project Area (Table 10.10).

Table 10.10 Environmental invasiveness and impacts of weeds in the Project Area

Rating	Species	Common name	Environmental	
			Invasiveness	Impacts
High	<i>Acacia farnesiana</i>	Mimosa bush	Yes	Yes
High	<i>Aerva javanica</i>	Kapok bush	Yes	Yes
High	<i>Calotropis procera</i>	Calotrope, Rubber tree	Yes	Yes
High	<i>Cenchrus ciliaris</i>	Buffel grass	Yes	Yes
High	<i>Passiflora foetida</i>	Stinking Passionfruit	Yes	Yes
Moderate	<i>Clitonia ternata</i>		Yes	–
Moderate	<i>Leucaena leucocephala</i>	Leucaena	Yes	–
Moderate	<i>Parkinsonia aculeata</i>	Parkinsonia	Yes	Yes
Moderate	<i>Urochloa mutica</i>		Yes	–
Mild	<i>Echinochloa colona</i>		Yes	–

Source: Department of Conservation and Land Management (1999) *Environmental Weed Strategy for Western Australia*.

Invasiveness refers to the ability of the species to invade the bushland in good or excellent condition and environmental impacts refers to the ability to change the structure, composition and function of an ecosystem.

Those weeds with a 'high' rating indicated these weeds need to be prioritised for control. Those with a moderate rating indicates that control should be considered after those with 'high' rating. This strategy would determine the priorities for weed control in the conservation areas of the Project Area.

Details of the necessary monitoring would be developed in the EMP but, as a minimum, would include assessment of the abundance of indicator species, and the prevalence and rate of spread of weeds in the reserves and buffer areas.

Quarantine measures that would be implemented for the control of weeds include the following:

- Interstate quarantine would be maintained.
- During project development, all construction vehicles would be washed down to the standards required by AGWEST to prevent transportation of soils and/or weeds into the Project Area. A wash-down site would be established at the main entrance to the Project Area. All vehicles entering construction areas, even private cars, would be washed down to remove seeds and soil.
- All site vehicles would be site-dedicated as much as possible, thus limiting cross-contamination from outside areas.
- If borrow is required, it would be obtained from surveyed weed-free sites.

Currently, several invasive species have been recorded within the Project Area, including wild passionfruit and parkinsonia. Management of these species would be undertaken as part of the management of conservation areas.

10.5.4 Feral and pest animals

Of the feral and pest vertebrates recorded for the Project Area, the Parks and Wildlife Commission of the Northern Territory has recognised the dingo as an important component of the region's ecosystems, although it can be a significant predator of livestock. Livestock would be removed from the Project Area and, therefore, the presence of this species should not continue to be a problem.

Donkeys, horses and cattle impact greatly on the vegetation along river frontages and other perennial water sources (Government of Western Australia 1997a). As river frontages would be conserved and the area destocked of cattle, it is anticipated that the condition of these areas would improve. CALM has undertaken a successful aerial shooting programme for donkeys at the Lower Ord Ramsar Site (Department of Conservation and Land Management 1998). Within the Project Area donkeys have been largely controlled by aerial shooting and only small populations have survived.

Rats and mice are rarely a problem in ORIA Stage 1 but management of these would be considered prior to the commencement of development. Wide-scale baiting and poisoning would be discouraged as three native *Rattus* species occur in the area, and the potential impact of baiting programmes on the native fauna is not fully understood. In the Herbert River canefields, Bellamy and Robinson (1998) noted that the number of owls in the area decreased as the area of cane-field increased. These birds catch and eat mice and rats. Halvorsen (1998) recorded that a 'single owl family can eat over 2,000 rats per year'. The need for owl nest-roost boxes would be assessed and, if required, incorporated in the Project Area.

Ecologia (1997) recorded feral cats in the Project Area. Cats as domestic pets are sometimes used for the control of mice and rats. In future, pet cats would be prohibited within the Project Area. The impact of cats on native fauna is substantial. They are exceptional predators and eat a wide range of native vertebrate and invertebrate animals reducing the populations of common and threatened native species. The Parks and Wildlife Commission of the Northern Territory and CALM are undertaking research on methods of cat eradication.

There is the potential to introduce animals that would have a damaging effect on some aspects of the biological environment. The spread of cane toad (*Bufo marinus*) from coastal Queensland across Northern Australia is an example. If the current rate of spread continues, the species may reach the Kimberley within the next ten years (Department of Conservation and Land Management 1998). However, it could occur before then if the species were inadvertently introduced into the region or the ORIA.

Mosquitoes are the vectors or potential vectors for several human diseases found across the Kimberley and Northern Australia, including Ross River virus, Barmah Forest virus and Australian encephalitis. In addition, they are nuisance pests. The public health issues associated with mosquito populations are discussed further in Chapter 14.

10.5.5 Public access

A strategy for public access through the proposed conservation areas would be developed. Consideration would be given to developing walk-trails, rather than roads, with adequate parking facilities provided for vehicles. The trails would be obvious yet unobtrusive, well placed and clearly designated.

Areas in and around the Project Area are currently utilised for recreational and, in the case of Miriung and Gajerrong people, cultural purposes; however, with improved access, the incidence of human impact could increase as a result of the proposed development. Signage about the Project Area and surrounds, and defined roads or tracks to the more popular areas, should assist with management. At popular areas (e.g. Keep River) camp grounds complete with composting toilets may need to be established.

As required by CALM and the Parks and Wildlife Commission of the Northern Territory, dogs and cats would not be permitted in conservation areas.

10.5.6 Borrow materials and rehabilitation

Gravel and other borrow materials would be required for road construction and ongoing maintenance. There would be a preference for the utilisation of existing borrow pits and quarries within the Project Area as sources of these materials.

Rehabilitation of any sites disturbed during the proposed development would be undertaken progressively using seed of species collected from the Project Area. Areas disturbed during development of the infrastructure would be rehabilitated as each stage of the work is completed, particularly those drainage channels designated as conservation-vegetation corridors.

Where possible, topsoil would be utilised immediately or removed and stockpiled for later use on disturbed areas. Once the development was complete, the topsoil would be spread over the disturbed areas, allowing seeds and root stock stored in the soil to germinate and become established. Active reseeding of some areas may also take place. Monitoring of the success of rehabilitation would be undertaken.

A seed collection programme would be undertaken before vegetation is cleared. A seed mix appropriate to the area to be rehabilitated would be prepared and scattered over the disturbed areas. Alternatively, seedlings could be germinated and planted out at the commencement of the wet season. Only seeds of plant species endemic to the Project Area would be used in revegetation projects.

10.5.7 Monitoring

The EMP (Section 16.5 and Appendix O) would include a detailed monitoring component for each of the issues being managed. Some of the features associated with environmental monitoring being considered for use in the proposed development include:

- ongoing data collection to improve the national, State, Territory and local regional databases; biodiversity baselines; environmental effects understanding; and environmental risk assessment. Examples could include Gouldian Finch records and monitoring, additional records of rare and priority flora and fauna species, successful methods of removal of flora and fauna species;
- a rigorous quality assurance/quality control programme;
- justification (including cost estimates) for all monitoring components such as programme design, laboratory analysis, data acquisition, fieldwork, analysis and reporting, and communication and liaison;
- baseline, compliance monitoring;

- interactive feedback and mitigation requirements as part of a continuous improvement cycle;
- auditing requirements;
- community involvement and liaison, including regular reporting to the public and an ongoing schedule of meetings to discuss monitoring information and trends.

11 Land use

This chapter describes the historical and current land-use patterns within and surrounding the Project Area. Potential changes to land use associated with the proposed development are discussed, together with proposed management measures. Traditional use of the region, Aboriginal cultural heritage issues and other aspects of specific relevance to Aboriginal people are addressed in detail in Chapter 12.

11.1 HISTORICAL EUROPEAN LAND USE

Pre-1960

The first detailed records of the East Kimberley were made by Alexander Forrest during his 1875–79 expedition, where he noted the irrigation potential of the Ord River area (Western Australian Government 1964).

After Forrest's expedition, flocks of sheep and cattle were moved into the region to create pastoral stations in 1884–85 when the Buchanan, Durack and McDonald families moved to the district (Western Australian Government 1964) primarily from Queensland. The discovery of gold at Halls Creek around 1885 and more substantially in southern Western Australia in the 1890s, created a dependable market for meat, and cattle grazing soon became a dominant part of the local economy.

The town of Wyndham was gazetted in 1886. In 1918 the Wyndham abattoir was built and it became the natural focus for the processing and sale of beef (Ministry for Planning and the Kimberley Development Commission 1999). By 1920, cattle numbers in the Kimberley had risen to over 500,000. Thereafter, however, the cattle population has remained virtually static and is now in decline.

Despite Forrest's early recognition of the irrigation potential of the Ord River it was not until 1942 that an experimental irrigation area of approximately 5 ha was developed on the banks of the river in the area known as Carlton Reach. The area was placed under the control of the Agriculture and Public Works departments (Western Australian Government 1964). In 1943, survey work was undertaken for proposed dam sites, basin capacity, access roads, diversion dams and main irrigation channels. In 1945, the Kimberley Research Station was established on the site currently occupied by the Frank Wise Institute, to determine the likelihood of successfully irrigating sugar, cotton, rice and safflower from the proposed Ord River Dam.

In the early 1940s, a Jewish community considered the establishment of an agricultural settlement in the Kimberley. Approximately 120 lots covering a total area of some 200 km² were surveyed in riverine country between the Ningbing Range and

the Onslow Hills some 100 km north of Kununurra. The development did not reach fruition.

During World War II the Australian defence forces used the now disused airstrip at the Kneebone stockyards, located immediately east of the Keep River Plain.

Post-1960

The Kununurra Diversion Dam was completed in 1963 and irrigation from the dam commenced in April that year. Safflower, cotton and rice were the first crops grown.

Kununurra developed as the centre for irrigated agriculture with some seventy houses constructed by 1964 together with two service stations, two general agencies, a police station, a concrete culvert factory and a cotton ginnery capable of harvesting 1,400,000 lb (c. 635,600 kg) per season (Western Australian Government 1964). In 1964, and again in 1967, the Government of Western Australia presented submissions to the Commonwealth Government seeking financial assistance to construct the Ord River Dam and associated irrigation channels, land development and service buildings (Western Australian Government 1967).

While the area of crops under irrigation grew steadily and rapidly in the early 1970s, reliance on pesticides to control insect pests also grew. Development of resistance to pesticides in the resident insect populations, particularly *Heliothis*, caused failure of a number of crops, especially cotton in 1974.

In 1985, the Wyndham meatworks closed and there was a shift towards the export of live cattle to the Indonesian, Malaysian and Philippine markets, as well as the Katherine meatworks. Since that time, open-range grazing has become more integrated with the establishment of cattle fattening operations utilising irrigated pasture and leucaena.

In recent times agricultural processing facilities have been developed. A sugar mill with the capacity to crush 540,000 t/a of cane was constructed in 1995–96 by Ord Sugar Pty Ltd and there are currently approximately 3,800 ha of irrigated land under sugarcane. Transgenic varieties of cotton offering greater resistance to pests have also been introduced for large-scale trials, and a ginnery was established in 1997.

Mineral exploration in the Project Area has occurred since the 1960s, with extensive exploration of a lead, zinc and silver deposit at Sorby Hills. More recently, mineral exploration has focussed on petroleum beneath the Keep River Plain. Exploration for alluvial diamonds, in paleochannels formed by the Ord River, has occurred in the west Ivanhoe area.

11.2 CURRENT LAND USE IN AND AROUND THE PROJECT AREA

The Project Area and its surrounds have a diverse range of land uses, including pastoral and irrigated agriculture, tourism and recreation, minerals exploration and mining, and nature and heritage conservation. These land uses are shown in Figure 11.1 and are described in the following sections.

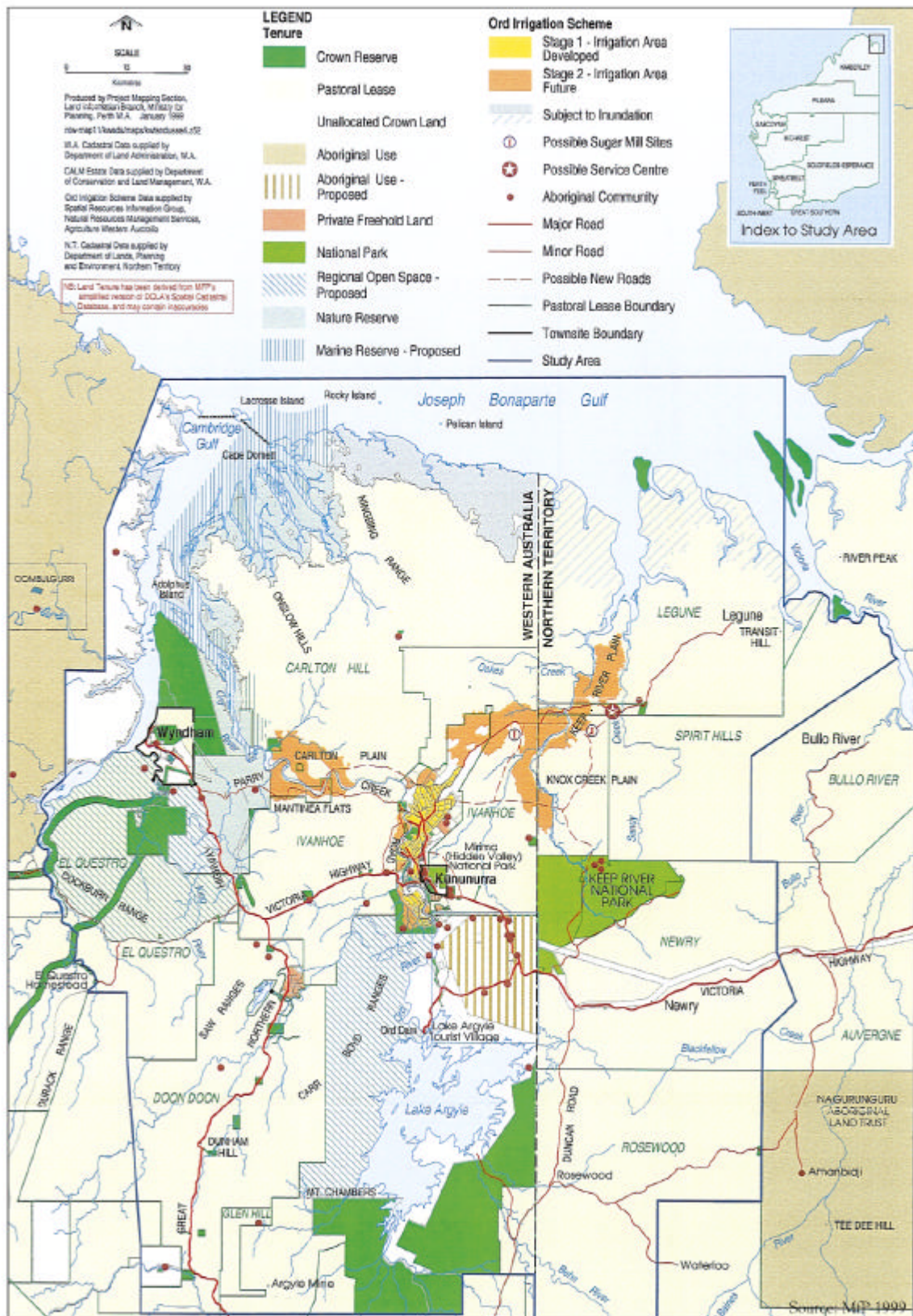


Figure 11.1 Land Use in the vicinity of the Project Area

11.2.1 Agriculture

Pastoralism

Pastoral leases associated with Ivanhoe Station in Western Australia, and Legune and Spirit Hills Stations in the Northern Territory cover most of the Project Area.

Grazing of cattle for beef production is a major local industry and more than half of the Kununurra–Wyndham area is used for pastoral activities (Ministry for Planning and the Kimberley Development Commission 1999). Total stock numbers were estimated at between 450,000 and 500,000 in the Kimberley in 1998. Stock numbers are currently lower than in previous years due in part to the influence of the brucellosis and tuberculosis eradication campaigns (Matt Bolum, Agriculture Western Australia, *pers. com.*, 17 November 1998). In addition, destocking of conservation areas has reduced total stock numbers.

The vegetation on the black-soil plains of the Ivanhoe Land System in the east Kimberley forms a valuable source of fodder for cattle, although that vegetation is not as good as that on the Mitchell and Flinders grass plains, which occur on black cracking clays on the Barkly Tablelands of the Northern Territory and in western Queensland. Stocking rates on individual areas are highly dependent on the condition of the vegetative cover. When good conditions prevail, the Ivanhoe Land System may support ten adult equivalents per square kilometre. The same area in fair or poor condition may support only as few as five or as little as one adult equivalent per square kilometre respectively (Matt Bolum, Agriculture Western Australia, *pers. com.*, 17 November 1998).

In 1996–97 some 1,400 ha of leucaena and hay were irrigated in the ORIA Stage 1 area to support cattle-grazing.

The majority of the cattle sold from the Kimberley are exported live via port facilities in Wyndham, Darwin, Broome and Port Hedland, while smaller numbers are processed at the Katherine abattoir. Traditional offshore markets have been in South East Asia, though in recent time markets have opened in the Middle East, including Libya and Egypt (Matt Bolum, Agriculture Western Australia, *pers. com.*, 17 November 1998).

Weed control is an important issue for the pastoral industry and Noogoora burr, belly-ache bush, mesquite and *Parkinsonia* and *Crotalaria* species can cause discomfort to animals or present a physical obstruction to sources of water. At present, rubber-vine and parthenium have not entered the Kimberley although they are present in Queensland. Another potential pest is *Mimosa pigra*, which could enter from the Northern Territory. This woody weed is highly invasive of waterways and floodplains. Maintaining strict quarantine measures at the Western Australian border is the main management measure used to prevent introduction of major pest species and the subsequent economic and environmental damage this would cause.

Clearing of vegetation on pastoral leases in the Northern Territory can only be carried out with the written approval of the Pastoral Lands Board, whose consent is required for any works other than fixed improvements such as fences and buildings, eradication of noxious weeds, and selective clearing of woody weeds over small areas of less than 2 ha (Department of Lands, Planning and Environment 1998). A similar requirement

exists in Western Australia, where the approval of the Commissioner for Soil and Land Conservation is required for all proposals to clear more than 1 ha of land.

Various leasehold improvements have been developed in the Project Area including fencing, holding yards, gates, groundwater bores, tanks, small dams and aircraft landing strips. A number of semi-formal and informal rubbish dumps also exist and some areas have been quarried to provide road construction materials.

Irrigated cropping

Irrigated cropping in the Kimberley is focused on ORIA Stage 1 within the Ivanhoe and Packsaddle plains straddling the Ord River (Figure 11.1).

A detailed description of ORIA Stage 1 is presented in Chapter 2.

11.2.2 Mining

The Argyle Diamond Mine is the only major mining activity in the Kununurra–Wyndham area (Ministry for Planning and the Kimberley Development Commission 1999). A local small-scale industry has developed in Kununurra based on zebra stone quarried around Lake Argyle and other local stone.

Most of the Kununurra–Wyndham area is covered by *Mining Act 1978* and *Petroleum Act 1967* exploration and mining tenements administered in Western Australia by the Department of Minerals and Energy. In the Northern Territory, the Department of Mines and Energy administers exploration licences and mining permits under the provisions of the *Mines Act 1980*.

The permits covering land in the vicinity of the Project Area are presented in Table 11.1. The locations of the tenements near to the Project Area are indicated in Figure 11.2.

In Western Australia a standard tenement clause has been attached to all permits issued in the ORIA since the 1970s. This requires that in the vicinity of any ‘*existing or planned irrigation area, or on any strip of land within 50 m of the banks of a Public Works Department irrigation channel, drain or maintained water course*

(e) No mining, other than exploration ...[may be carried out] without written approval of the State Mining Engineer and the Director of Engineering ...;

(f) No extension of previously approved surface mining operations...[may be carried out] without written approval of the State Mining Engineer and the Director of Engineering;

(g) Exploration ... confined to surface geological, geophysical and/or geochemical surveys, and drilling unless the written consent of the District Engineer, Public Works Department, Kununurra, is first obtained.’

A limited amount of mining exploration occurs in the region. Exploration for alluvial diamonds is presently under way in the west Ivanhoe area. Deposits of lead, zinc and silver are known to exist at Sorby Hills, located northeast of the Pincombe Range, but as yet the deposit has not proved sufficiently attractive for commercial development. The Weaber Gas Field, situated at the southern end of the Keep River Plain, is not commercially exploited at the present time. A number of spudded gas wells exist

within the Project Area in both Western Australia and the Northern Territory. In places, seismic lines were cleared across the plains to facilitate mineral exploration.

Table 11.1 Mining and exploration permits in the vicinity of the Project Area

Mining permit number	Holder
M80/285	Triako Resources
M80/196	Triako Resources
M80/286	Triako Resources
M80/197	Triako Resources
M80/287	Triako Resources

Two oil and gas permits covering the Project Area exist in the Northern Territory. These are summarised in Table 11.2.

Table 11.2 Oil and gas permits intersecting with the Project Area

Exploration/mining permit number	Holder
EP66	Amity Oil NL, Geopetro Company, Bonaparte Gulf Oil and Gas Pty Ltd, Frontier Bonaparte Pty Ltd
RL1	Amity Oil NL, Bonaparte Gulf Oil and Gas Pty Ltd, Frontier Bonaparte Pty Ltd

11.2.3 Fishing and aquaculture

Recreational and commercial fishing in the Kimberley is an important part of the local lifestyle and economy. Fisheries estimates that some 50,000 tourists fish in the Kimberley each year (Ministry for Planning and the Kimberley Development Commission 1999). Aboriginal people fish primarily for food, but great emphasis is also placed on the socio-cultural importance of fishing.

Recreational fishing participation in the Kununurra–Wyndham area is well above national averages. Important fishing locations include marine and estuarine areas as well as permanent waterholes and the tidal areas of the Keep River, the entire length of the Ord River downstream of the Argyle Dam and Lake Argyle itself. Awareness of the need for sustainable fishing practices is high, and management planning initiatives implemented to control fishing in the Ord River include the creation of a Fish Habitat Protection Area. Release of water from the Argyle Dam to provide hydroelectric power constitutes a significant portion of the base flow in the Ord River and has to a large extent created the current fishing environment.

The local commercial fishing industry includes the Lake Argyle Catfish Fishery as well as a hatchery, and a small-scale barramundi farm on Lake Argyle. Aquaculture development potential in the area is substantial and the Kimberley Aquaculture Development Plan (Fisheries Western Australia and Kimberley Development Commission 1995) identified the following opportunities:

- cage culture in Lake Argyle and Lake Kununurra for grow-out of juvenile barramundi, bream species and eel;

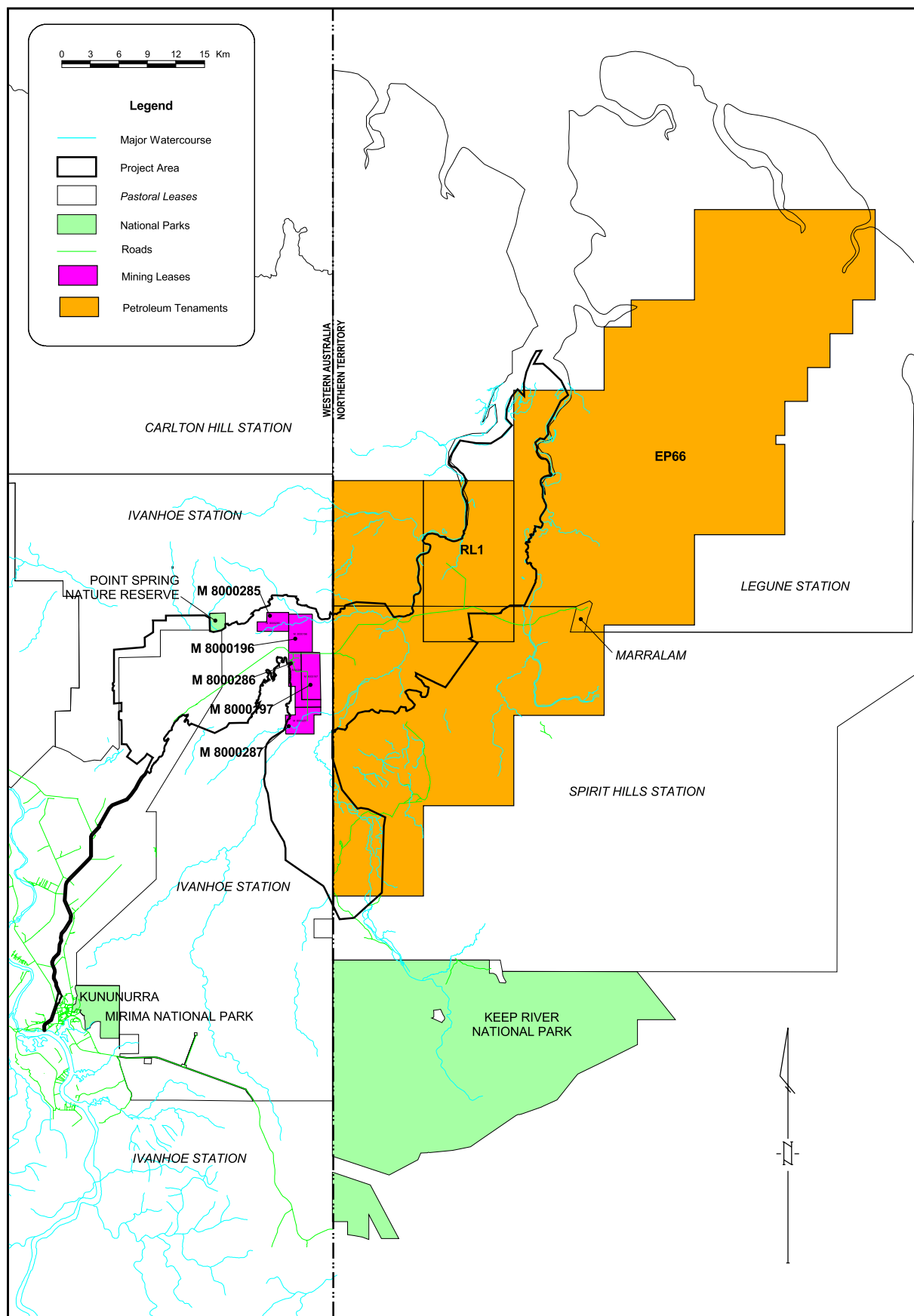


Figure 11.2 Mining permits in the Project Area

- pond culture and grow-out of barramundi, bream species and prawns in the north-eastern floodplains of the lower Ord River (Carlton Station), the Packsaddle Plain, the Ord River West Bank and the western floodplains of the lower Ord River;
- hatchery production of fish at Lake Argyle.

Assessment of potential sites for aquaculture ventures as part of ORIA Stage 2 has been undertaken (Sinclair and Ostle 1998); however, no firm development proposals for the Project Area exist at the present time.

11.2.4 Tourism and recreation

Northern Australia has become an increasingly popular holiday destination for Australian and international tourists because of the region's scenic beauty, unique landforms, and relaxed and distinctively Australian lifestyle. The Tourism Commission of Western Australia has estimated that 206,000 visitors travelled to the Kimberley Region in 1994–95.

Tourism is largely a seasonal industry, with an estimated 60% of tourists arriving during the dry season (April to September) when temperatures are low relative to the wet season. Kununurra acts as the departure point for tourist visits to Purnululu National Park (Bungle Bungle) and other major attractions including Lake Argyle, the Ord River, Hidden Valley National Park, Kelly's Knob Lookout, Ivanhoe Crossing, Lake Kununurra and Valentines Pool, as well as local national parks and reserves including the Keep River National Park. Water-dependent activities include tour boat operations on Lake Argyle as well as on the Ord River between Kununurra and the diversion dam and the river downstream of the diversion dam.

There are also a number of regular social and sporting activities in the region (Kimberley Tourism Association 1998):

- Lake Argyle Sailing Regatta (April)
- Kununurra Rodeo (April)
- Dam to Dam Dinghy Race (June)
- Agricultural Show (July)
- Kununurra Rodeo (July and August)
- Wyndham Races (August)
- East Kimberley Art Show (August)
- Kununurra Race Meeting (August)
- Kununurra Cup Race Day and Ball (August)
- Round Australia Car Rally (September)
- Night Rodeo (September)
- El Questro Barra Bash (October).

In addition to the events listed above, annual events include a diamond hunt, the Ord Festival, and the Kununurra Bachelors and Spinsters Ball (Kununurra Tourist Bureau, *in litt*, 5 November 1998).

In Kununurra there are currently four hotels, a number of budget (backpacker) accommodation locations and four caravan parks. The lack of available tourist accommodation in Kununurra during the dry season has been an issue for a number of years and is viewed by the industry as a limiting factor for future tourism growth. The industry also considers the limited transportation links to the area, including the lack of an international airport, to be a constraint in terms of future tourism growth.

11.2.5 Transportation

The Victoria Highway is the only sealed road that links Kununurra with the Northern Territory in the east and Wyndham to the west. The Great Northern Highway and the Gibb River Road provide access to the remainder of Western Australia and the Kimberley respectively. An unsealed road (the Weaber Plain Road) links Kununurra to the Project Area.

Main Roads Western Australia recently initiated a planning study assessing road needs within the region. The outcomes of this study are anticipated to be available by late 1999.

Road transport across the Western Australia – Northern Territory border is monitored at the quarantine checkpoint on the Victoria Highway some 40 km east of Kununurra. Checkpoint statistics have been maintained and processed until recently by the Kimberley Tourism Association in Broome. A summary of vehicle entry data for 1994 is presented in Table 11.3.

Table 11.3 Vehicle numbers entering Western Australia via the Kununurra Quarantine Checkpoint, 1994

Vehicle type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Cars/station wagons	354	288	242	468	562	981	1,580	1,348	823	593	362	473	8,074
Vans/4WD	474	366	360	856	1,071	1,670	2,422	2,065	1,379	1,056	624	480	12,823
Trucks	172	150	135	242	300	299	440	465	493	550	329	258	3833
Coaches/buses	29	31	25	100	59	63	80	98	76	54	43	30	688
Motorcycles	21	13	11	35	61	36	65	40	49	35	43	33	442
Caravans/trailers	45	13	53	206	495	1,012	1,730	1,392	620	275	150	151	6,142
Total	1095	861	826	1907	2,548	4,061	6,317	5,408	3,440	2,563	1551	1425	32,002

Note: Coach/bus numbers for April, July and December are estimates based on 1995 data.

Source: Kimberley Tourism Association.

The peak tourism period is June to August when temperatures are cooler and road access is not affected by local flooding.

11.2.6 Conservation reserves

Figure 11.1 shows the conservation reserves in the region. The nearest of these to the Project Area are:

- the Point Spring Nature Reserve—abutting the Weaber Plain portion of the Project Area;
- the Keep River National Park—located approximately 6 km south of the Project Area on the Knox Creek Plain portion of the Project Area.

Chapter 10 provides a description of the conservation reserves in the region and their significance to the Project.

11.2.7 Population and settlements

There is only one permanent residence within the Project Area, the Spirit Hills Station homestead. The pastoral lease for Spirit Hills Station is owned by the Northern Territory Land Corporation and subleased to the Carlton Pastoral Company.

A number of permanent residences are located within 20 km of the Project Area; these include:

- the Marralam Aboriginal community (consisting of around twenty to twenty-five people), located approximately 15 km east of the Project Area;
- the Policeman's Waterhole, Bucket Spring and Bubble Bubble Springs Aboriginal communities, located within the Keep River National Park (and reported to be sparsely occupied particularly during the wet season).

The Kumbarumbra Aboriginal community in the vicinity of Mt Septimus between Eight Mile Creek and the Keep River is reported to have been abandoned.

The Legune Station homestead is located some 30 km northeast of the northernmost reaches of the Keep River Plain.

11.2.8 Port of Wyndham

The proposed port storage facilities at Wyndham would be sited on land zoned for industry. Consequently no rezoning application would be necessary for construction of this facility, although building approval would be required. Surrounding land is also zoned 'industrial' or for 'port purposes', and the proposed storage facilities are considered to be compatible with these land uses.

11.3 REGIONAL DEVELOPMENT AND LAND-USE CONTROL

11.3.1 Strategic planning

A Kununurra–Wyndham Area Development Strategy (KWADS) is now being developed by the MfP with the Department of Lands, Planning and Environment. This process is being steered by a committee with agency representatives from both the State and the Territory. The objective of the KWADS is to provide assistance to, and guide development in, the area (Ministry for Planning and the Kimberley Development Commission 1999).

The draft KWADS released for public comment in late August 1999, takes into consideration the future development of the Project Area as well as the proposed

irrigation areas on the Carlton Plain, the Ord River West Bank and Green Swamp. Decisions on regional development are also guided by the need to avoid national parks, wildlife reserves, and sites of cultural heritage or other significance.

The draft KWADS land-use plan indicates the anticipated locations of regional infrastructure and development. In addition, the strategy has developed objectives for key industries within the area, including the realisation of the area's irrigated agriculture potential through the release and development of suitable land, and through the application of planning or policy ordinances that help to minimise conflict with, or impact from, other uses (Cane Spaseski, Ministry for Planning, *pers. com.*, November 1998).

11.3.2 Statutory planning

Western Australia and ORIA Stage 1

Development within Kununurra and ORIA Stage 1 is controlled through the provisions of the Kununurra Town Planning Scheme. Development outside the areas covered by the scheme may occur within, for example, the provisions of leasehold conditions or under specific other legislation such as the *Mining Act 1978*.

The Kununurra Town Planning Scheme defines two different agricultural production zones. A Rural A zone with a minimum lot size of 80 ha is designed to accommodate broad-acre farming. A Rural B zone with a minimum lot size of 8 ha (and maximum of 80 ha) allows more intensive horticultural production. Rural-residential living is permitted within a limited number of areas through a Rural C zone having a minimum lot size of 2 ha (and a maximum of 8 ha) (Ministry for Planning and the Kimberley Development Commission 1999). One intent of this zoning is to protect the integrity of the irrigation area from urban development. Another intent is to minimise the risk of inappropriately locating residential developments within farming areas.

Pastoral lease is the dominant land tenure within the Western Australian portion of the Project Area. Pastoral leases in Western Australia, together with conditions of lease, have been granted under the *Land Act 1933*, which was recently repealed and replaced by the *Land Administration Act 1997* (Steve Turner, Department of Land Administration, *pers. com.*, 16 November 1998). All pastoral leases in Western Australia expire in 2015.

Northern Territory

The Department of Lands, Planning and Environment (DLPE) administers statutory and strategic planning in the Northern Territory as well as land tenure. Land-use control over the Northern Territory portion of the Project Area is currently effected through conditions on the various pastoral leases administered under the *Pastoral Land Act 1996*. However, this control only applies to lawful pastoral uses. A change to the tenure over part of the pastoral leases is required to provide for substantial uses not allowed on a pastoral lease, including irrigated agriculture.

The DLPE has commenced work on a planning scheme that, subject to due process, would cover all of the Northern Territory. Within this broad framework, it is intended that there would be primary focus on regions (largely based on catchments), then sub-

regions (largely based on cadastral and/or administrative boundaries) followed by districts, localities and precincts as deemed appropriate. Completion of all components is a long-term task, and ranking of priorities is regularly reviewed (Graham Bailey, Department of Lands, Planning and Environment, *pers. com.*, 14 January 1999).

A Bill to amend the *Planning Act 1993* has been passed and is scheduled for commencement in March 2000. Broadly, its purpose is to refine and reinforce the existing strategic planning framework.

Subject to the completion of a Northern Territory Planning Scheme, and on the basis that the Project Area within the Northern Territory were developed as freehold land, it is possible that application of a planning scheme would come into effect.

11.4 LAND TENURE WITHIN THE PROJECT AREA

The Project Area is impacted by native title and land rights claims in Western Australia and the Northern Territory. The approach taken by Wesfarmers–Marubeni and the Water Corporation with respect to native title and land rights issues in the Project Area is for resolution by way of a negotiated settlement with the Miriuwung and Gajerrong people (Chapter 12 refers).

The preferred land tenure of particular portions of the Project Area such as the proposed Conservation Area, would vary depending upon their intended use, and is subject to a resolution that satisfies all of the affected parties (see Table 11.4.)

Table 11.4 Preferred land tenure within the Project Area

Land Status	Preferred Land Tenure	Land ownership	Land Management
Developed Land	Freehold	Wesfarmers–Marubeni/Individual Owners	Wesfarmers–Marubeni/Individual Owners
Sugar mill site and airstrip	Freehold	Wesfarmers–Marubeni	Wesfarmers–Marubeni
Construction camp/workers camp	Freehold	Wesfarmers–Marubeni	Wesfarmers–Marubeni
Conservation area	Subject to resolution	Subject to resolution	Environmental Management Entity*
Airstrips	Special-purpose reserve	Subject to resolution	Wesfarmers–Marubeni
Public roads	Special-purpose reserve	WA and/or NT Government	WA and/or NT Governments
Irrigation, drainage and flood protection infrastructure	Freehold	Water Corporation	Water Corporation
Powerlines and associated infrastructure	Special-purpose reserve	WA and/or NT Government	Subject to resolution
Communications sites	Special-purpose reserve	WA and/or NT Government	Subject to resolution

* Refer to Chapter 16 for the roles and responsibilities of the Environmental Management Entity.

11.4.1 Developed land

Wesfarmers–Marubeni would seek freehold title over the developed land. Upon resolution of the native title and land rights issues, it is envisaged that the Western Australian and Northern Territory Governments would issue a development lease to Wesfarmers–Marubeni. The Project Area would be progressively converted to freehold once the development lease conditions have been met.

11.4.2 Sugar mill site and airstrip

Wesfarmers–Marubeni would seek freehold title over the land underlying the sugar mill site and its associated airstrip.

The airstrip has been designed to service the sugar mill and the construction camp/workers camp and secure land tenure would enable the airstrip to be maintained, thereby ensuring health and safety standards are met.

11.4.3 Construction camp/workers camp

Wesfarmers–Marubeni would seek freehold title over the land underlying the construction camp which may eventually become a workers camp. It is considered appropriate that the construction camp/workers camp would be on freehold land to ensure that regulations are enforced with contractors and employees.

11.4.4 Conservation area

The Conservation Area within the Project Area would be managed by the Environmental Management Entity (see Chapter 16).

The Conservation Area would be established to ensure those significant habitats are protected. It is envisaged that the native title rights of the Miriuwung and Gajerrong people with respect to access to the Conservation Area would be maintained for the purposes of pursuing traditional practices on the land and waters.

It is envisaged that access to locations on the Keep River within the Conservation Area would remain open with designated recreation sites for fishing and picnicking purposes being managed by the Environmental Management Entity. Access to the remainder of the Conservation Area would be restricted to control erosion and weeds as well as to protect the regeneration of the flora and fauna habitats.

11.4.5 Airstrips

Wesfarmers–Marubeni would seek special purpose reserves over the land underlying the airstrips that would be required in order to service the farms. Wesfarmers–Marubeni would be responsible for the management of the airstrips (see Chapter 16).

11.4.6 Roads

Public roads in the Project Area would be contained within special–purpose reserves vested in the Western Australian and/or Northern Territory Governments.

Roads on and leading to individual farms would be private property managed by Wesfarmers-Marubeni and/or individual owners.

11.4.7 Irrigation, drainage and flood protection infrastructure

The land underlying the irrigation channels, drains, and flood protection infrastructure would be freehold vested in the Water Corporation.

11.4.8 Powerlines and associated infrastructure

The land underlying the powerlines and associated infrastructure would be contained within special-purpose reserves vested in the Western Australian and Northern Territory Governments.

11.4.9 Communications sites

The land underlying the communications sites would be contained within special – purpose reserves vested in the Western Australian and Northern Territory Governments.

11.5 LAND-USE IMPACTS AND MITIGATION MEASURES

11.5.1 Pastoral uses

Potential impacts on pastoral land use would include:

- a reduction in size of existing pastoral leases due to land being excised for the proposed development;
- the development of road networks that would alter access in the region;
- potential synergies with the Project, including opportunities for irrigated pasture or leucaena grown on independent farms, or lot-feeding with molasses;
- the potential introduction of noxious flora (weeds).

Displacement of pastoral activities

Displacement of existing pastoral activities would be an unavoidable consequence of the proposed development.

Removal of stock from the Project Area would occur progressively and would finally cease as development advances, but the areas involved would be relatively small in comparison with the existing pastoral leases.

As a result of the proposed excision of the Project Area from Legune Station, the northwestern portion of Legune Station would be cut off from the remainder of the pastoral lease. Some rationalisation of pastoral lease boundaries may therefore be required.

Pastoral activities would be incompatible with the land-use objectives proposed within the Project Area. As a consequence, the boundary of the Project Area would be fenced, where appropriate, to prevent the ingress of cattle.

Development of road networks

Development of roads would lead to improved access to Kununurra for pastoralists and others along the Kununurra–Legune road. This would reduce the time required to obtain provisions and access medical assistance if required.

Road development may also have perceived negative impacts resulting from an increase in human impact in and around the Project Area. These negative impacts could include problems for stock management (e.g. gates being left open and disturbance from dogs); risk of fire (e.g. from camping and fishing activities); opportunities for spreading weeds; and general disturbance. Project development would include the erection of signs at strategic locations throughout the Project Area that would advise travelers that access to pastoral leases is restricted.

Potential synergies with the Project

Leucaena and other pasture crops are currently grown within ORIA Stage 1, and it is possible that some of the area proposed for independent farmers within the Project Area could also be used for these crops. This outcome would be beneficial to the pastoral industry by providing greater opportunity for fattening or finishing of stock prior to export.

Molasses and bagasse, which are by-products from raw-sugar production, are used elsewhere in Australia for lot feeding or supplementing the diet of cattle. Hence, it is possible that production of either or both of these by-products by the Project could support a lot-feeding or feed-supplementing industry.

Introduction of noxious flora

Increased opportunities for spreading of weeds would result from the use of agricultural machinery in the Project Area, as well as from increased vehicle and personnel movements in the region generally. Careful surveillance and control of weeds within the Project Area are proposed as part of the Project. Chapter 16 describes the allocation of responsibility for this task.

11.5.2 Tourism, recreation and conservation reserves

It is likely that regional tourism and recreation area usage in the region will continue to increase whether or not the Project proceeds. However, it is anticipated that improved infrastructure and services such as roads and accommodation resulting from the proposed development would lead to increased tourist numbers and to longer durations of stay.

Many of the current conservation reserves in the region are heavily utilised by tourists for recreational pursuits and nature study. Management of these areas currently ensures that these pressures do not reduce their conservation or tourism significance.

In Western Australia, national parks and nature reserves are vested in the National Parks and Nature Conservation Authority and managed by CALM. In the Northern Territory, conservation parks are vested in the Conservation and Land Corporation, and managed by the Northern Territory Parks and Wildlife Commission.

Increased tourism and population pressure are anticipated to have their greatest effects on popular tourist and ecological ‘nodes’ such as waterholes, waterfalls and scenic areas accessible by roads. Expectations for improved access to, and facilities at, these popular destinations are also likely to grow. Consequently, development of management plans and implementation of strategic monitoring programmes by the managing agencies would be required in the future.

Recreational visitation in and adjacent to the Project Area is presently focussed on particular activities such as fishing, and known accessible localities including the lower Keep River, and Point Springs. Access to these localities would be maintained, and in the case of the Keep River where it abuts the Conservation Area, managed by the Environmental Management Entity (EME). Measures to maintain the recreational values within the Project Area are detailed in the Environmental Management Plan EMP (see Appendix O).

11.5.3 Other issues

Quarantine

Subject to the outcome of current planning studies, it is possible that the Keep River National Park road would be constructed to enable all weather access to the Project Area from the Victoria Highway. If constructed, this would create a ‘loop road’ that would link Kununurra, the Project Area and the Keep River National Park. The road would also provide an alternative point of entry into Western Australia. Consequently, it may be necessary to relocate the present quarantine checkpoint and washdown facility eastwards, possibly to the junction with Duncan Road.

It is anticipated that quarantine matters would be dealt with by the joint Western Australian and Northern Territory Ministerial Council described in Chapter 16.

Sustainability of land-use changes

An objective of the Project is to create an irrigated agricultural industry, sustainable in perpetuity. Consequently, long-term land use in the Project Area is anticipated to remain agricultural. Protection of this land use may be necessary through a planning scheme mechanism to prevent subdivision of irrigation blocks or development of non-agricultural land uses that may conflict with agricultural practices.

12 Issues specific to Miriung and Gajerrong people

12.1 INTRODUCTION

The land encompassing the Ord and Keep rivers, including the Project Area, is of traditional and current significance to Miriung and Gajerrong people.

In 1998, Miriung and Gajerrong people successfully argued their native title rights before the Federal Court, resulting in the first determination for native title on the Australian mainland. The land subject to the determination is approximately 7,900km², and approximately 100km² of that land is located within the Project Area. The balance of the Project Area is currently subject to two additional native title claims and an Aboriginal land rights claim by the Miriung and Gajerrong people.

This chapter summarises the environmental issues in relation to the proposed development of specific interest to Miriung and Gajerrong people. It also describes how Wesfarmers–Marubeni and the Water Corporation have addressed or intend to address those issues, including cultural heritage, social impact and native title.

12.2 HISTORICAL OVERVIEW

Conflict between white pastoralists and Aboriginal people in the East Kimberley and the Northern Territory in the early years of the development of the pastoral industry was common. The Aboriginal people living off the land as they had done for thousands of years found their traditional way of life inconsistent with the newly established pastoral industry. A long campaign of resistance was waged by at least some Aboriginal people (Maurice 1985, 5).

Conflict between Aboriginal people and pastoralists continued until the early part of the twentieth century. This conflict resulted in the Horseshoe Creek Massacre (1901), the Mistake Creek Massacre (1915) and the Forrest River Massacre (1926). Encounters in the vicinity of Kununurra occurred at Skull Creek, Dingo Springs, Bucket Spring and Newry, and are recalled in stories told by Aboriginal people (Green 1978; Mulvaney 1996; Ross and Bray 1989; Shaw 1981; Thoorbiliny 1987).

The introduction of the pastoral industry had a marked and deleterious effect on the native fauna and flora, which resulted in a diminished opportunity for Aboriginal people to maintain their traditional lifestyle (Lee 1998). As a result the Miriung, Gajerrong, Murinpatha, Jaminjung and other Aboriginal people in the region, began to work for the pastoral lessees who had assumed management of significant areas of their traditional country.

Aboriginal people who worked on the pastoral stations were still able to practice their traditional lifestyle, conduct ceremonies, hunt and visit country on weekends and during the wet season. Aboriginal people reversed their traditional time for ceremonies to accommodate their employment on the pastoral stations in the 'dry', and movement and congregation for ceremonial activity in the 'wet' (Western Australian Planning Commission 1999).

The development of farmland in ORIA Stage 1 in 1963, provided opportunities for Aboriginal labour being used for weeding and casual gardening work. In the same year, the Mirima Aboriginal Reserve was established in Kununurra along with the new township. The establishment of the Reserve created the first permanent base for Aboriginal people, providing a place where people could remain rather than returning to the pastoral stations at the commencement of the working season (Willis 1980, 22). The Native Welfare Department Annual Report for 1962 noted that Aboriginal people were moving away from the pastoral stations and finding work in other places in and around Kununurra (Willis 1980, 29).

By the mid-1960s, farmers and pastoral lessees were competing for the services of Aboriginal workers who now occupied the Reserve. Farmers paid £20–30 per week, whereas the pastoral lessees paid less than £5 per week. As a consequence, many Aboriginal people moved to Kununurra (Willis 1980).

The advent of equal wages for Aboriginal people in 1969 in the pastoral industry dramatically decreased Aboriginal employment on the pastoral stations. This in turn resulted in the increased movement of Aboriginal people into towns such as Wyndham and the newly established Kununurra.

Between 1963 and 1976, the Aboriginal population of Kununurra grew from 77 persons to 438 persons, with a similar increase in Wyndham (Willis 1980).

Since the 1980s, Government policies have encouraged the establishment of Aboriginal 'homeland communities' (now commonly known as Community Living Areas). The purpose of these homeland communities is to support Aboriginal people to re-establish themselves on their traditional country. There are currently over 30 Aboriginal homeland communities in the Kununurra-Wyndham area, most of which are small with some being remote (Western Australian Planning Commission 1999). Negotiations are ongoing with the Western Australian Government to establish additional homeland communities to further enable Aboriginal people to maintain their links with their traditional country.

The Western Australian Government and, to a lesser degree, the Northern Territory Government have been involved in facilitating the development of the Ord River region since the construction of the Kununurra Diversion Dam in the early 1960s. The early development of the region occurred at a time when there was no legal requirement to consult with, or consider, Aboriginal issues. Consequently, since the late 1960s, Aboriginal people have actively sought to have their traditional rights recognised, to participate in the economic development process, and to share in the subsequent benefits of economic development.

12.3 CONSULTATION WITH MIRIUWUNG AND GAJERRONG PEOPLE

The Western Australian Government has undertaken consultations with Miriuwung and Gajerrong people from 1995-1998 in relation to the proposed ORIA Stage 2 developments. The consultations generally focussed on compliance with cultural heritage issues as well as

other issues that may affect the Miriung and Gajerrong people such as employment and training opportunities.

Wesfarmers–Marubeni and the Water Corporation have taken over the lead role in consultation with respect to the Project Area since being awarded an exclusive mandate in April 1998 to investigate the viability of developing the Project Area.

Wesfarmers–Marubeni and the Water Corporation recognise the need to establish a working relationship with the Aboriginal community and to have consistent, open and honest consultation with them and, specifically, with those Miriung and Gajerrong people likely to be directly affected by the proposed development. Extensive consultation is occurring with the Miriung and Gajerrong people, as well as with the Aboriginal representative bodies – the Aboriginal Legal Service (ALS), the Kimberley Land Council (KLC) and the Northern Land Council (NLC).

Wesfarmers–Marubeni and the Water Corporation have established a Community Relations Team of three staff to facilitate ongoing communication with the Miriung and Gajerrong people in relation to the proposed development. Two members of the team reside permanently in Kununurra, including a Project Co-ordinator and Community Relations Officer, and the third Perth-based member visits Kununurra on a regular basis.

A good working relationship has been established through regular interface between the Community Relations Team, the Miriung and Gajerrong people and the Aboriginal representative bodies.

The first official meetings between Wesfarmers–Marubeni, the Water Corporation and the Miriung and Gajerrong people occurred on 21 and 22 July 1998. On 21 July, a meeting was held at the Ski Beach on the Lake Kununurra foreshore, and was well attended by Miriung and Gajerrong people, as well as by representatives from the ALS, the KLC and the NLC. The purpose of the meeting was to enable Wesfarmers–Marubeni and the Water Corporation to outline the proposed Project and the planned development of the ERMP/draft EIS. The following day, representatives from Wesfarmers–Marubeni and the Water Corporation visited the Project Area to continue the discussions on site (see Figure 12.1). The two-day interaction session established a positive tone for future discussions and negotiations between the parties.

Since the initial meeting, Wesfarmers–Marubeni and the Water Corporation have attended regular meetings facilitated by the Aboriginal representative bodies to discuss and negotiate the cultural heritage assessment process, and other issues relating to Miriung and Gajerrong people.

In addition to meetings with the Aboriginal representative bodies, Wesfarmers–Marubeni and the Water Corporation have also convened regular meetings with the Miriung and Gajerrong people. The purpose of the meetings is to provide the Miriung and Gajerrong people and the Aboriginal representative bodies will feedback on the progress of the Project. These meetings commenced in February 1999 and are scheduled to occur at times that suit the attendance of Miriung and Gajerrong people. Wesfarmers–Marubeni and the Water Corporation formally invite the Miriung and Gajerrong people and the Aboriginal representative bodies to attend these meetings, which are generally well represented.

Figure 12.1 Consultation with Miriuwung and Gajerrong people in the Project Area on 22 July 1998



At the conclusion of each meeting, a summary of the issues discussed is provided to the Miriuwung and Gajerrong people and the Aboriginal representative bodies for their information. The Community Relations Officer also provides copies of this summary to representatives of the Miriuwung and Gajerrong families that were unable to attend the meeting.

Wesfarmers–Marubeni and the Water Corporation have also invited Miriuwung and Gajerrong people to participate in work undertaken directly for the ERMP/draft EIS. These invitations included:

- an invitation to participate in flora and fauna surveys conducted in May and June 1999;
- an invitation to view the locations of proposed test pits excavated by a Waringarri Aboriginal Corporation backhoe at the proposed sugar-mill site in April 1999.

Miriuwung and Gajerrong people participated on both occasions. The purpose of the former invitation was to create the opportunity for the documentation, in Miriuwung and Gajerrong language, of the various plants and animals to be recorded during the survey, and to allow cross-cultural interaction between the parties. For that exercise, the KLC was able to facilitate the involvement of Miriuwung and Gajerrong people in site inspections of the flora and fauna survey work (Figure 12.2).

Figure 12.2 Miriuwung and Gajerrong Traditional Owner examining fauna caught during the flora and fauna survey



Wesfarmers–Marubeni and the Water Corporation have demonstrated their commitment to significant consultation and ongoing dialogue with Miriuwung and Gajerrong people and the

Aboriginal representative bodies. This has allowed all parties to understand and to jointly own the issues and processes being employed and to resolve problems.

12.4 NATIVE TITLE AND LAND RIGHTS CLAIMS

12.4.1 Background

The 1992 High Court ‘Mabo decision’ overturned the concept of *terra nullius*. In reaction to the decision, the Commonwealth Government enacted the *Native Title Act 1993* (NTA), and established the National Native Title Tribunal to administer native title claims.

In December 1996, the High Court determined that native title may coexist with pastoral activities, but that pastoral lease rights would prevail if there was any inconsistency with native title rights. This decision is known as the ‘Wik decision’, after the Aboriginal group that brought the case to court.

The NTA requires that Governments proposing to deal with land where native title may exist, such as pastoral leases and vacant Crown land, must consult with Aboriginal people. This process is known as the ‘right to negotiate’.

12.4.2 Native title claims

In April 1994 (Claim WC94/2), August 1994 (Claim WC94/7), and January 1995 (Claim DC95/1), the Miriuwung and Gajerrong people lodged native title claims over a significant portion of the East Kimberley in Western Australia and the Northern Territory. The three claims cover the entire Project Area (see Figure 12.3).

As a result of the lodgment of the claims, proponents wishing to develop a significant portion of land in the East Kimberley must consult with Miriuwung and Gajerrong people. Wesfarmers–Marubeni and the Water Corporation began consultation with Miriuwung and Gajerrong people in July 1998, and the process is ongoing.

12.4.3 Aboriginal Land Rights claim

Unlike Western Australia, the Northern Territory has an additional legislative procedure by which Aboriginal people can claim land—the *Aboriginal Land Rights (Northern Territory) Act 1976* (ALRA). In accordance with the ALRA, Aboriginal people may claim unalienated Crown land outside of gazetted town areas and also land in which all interests are owned by, or on behalf of, Aboriginal people (e.g. reserves, missions etc.).

In accordance with the ALRA, the NLC has a statutory responsibility to lodge claims on behalf of ‘traditional owners’. One of the claims lodged by the NLC is known as the Legune Area land claim and it affects that portion of the Project Area contained within the Spirit Hills pastoral lease. The claim was lodged on behalf of Miriuwung and Gajerrong people.

The validity of the Legune Area land claim is currently the subject of Federal Court proceedings.

12.4.4 Native Title determination and appeal

On 24 November 1998, the Federal Court of Australia determined that Miriung and Gajerrong people have particular native title rights to a portion of their traditional land covered under native title claim WC94/2 (Lee 1998). The determination area covers approximately 7,900 km² and includes the Ord River, Lake Argyle and approximately 100 km² of the Project Area.

On 6 January 1999, the Western Australian Government and others lodged an appeal against the Federal Court determination. The full bench of the Federal Court of Australia heard appeal evidence from 26 July to 13 August 1999.

12.4.5 Settlement of Native Title Issues in relation to the Project

The entire Project Area comprises either land upon which native title has been determined (approximately 10,000 ha) or land currently the subject of native title claims (approximately 66,000 ha) (see Figure 12.3).

A native title determination, such as the determination made by the Federal Court on 24 November 1998, requires that native title holders be compensated for any temporary impairment or permanent loss of any or all of their native title rights. Furthermore, on land subject to a registered native title claim for which native title has not been formally determined, the claimants retain the “right to negotiate” over any proposed development of the land.

For land the subject of a native title determination and land the subject of a native title claim, the native title holders and claimants may voluntarily surrender their native title rights and interests by way of a negotiated settlement. Such a negotiated settlement is known as an Indigenous Land Use Agreement (ILUA).

A valid ILUA must conform to the provisions of the NTA, and may be registered with the National Native Title Tribunal. Typically, parties to an ILUA can include Aboriginal native title holders/claimants, Aboriginal representative bodies, project proponents and Governments. Mutually agreed benefits packages for the claimants/native title holders are a key element of any ILUA, in return for the voluntary surrender of native title rights and interests over the land. It is envisaged that particular rights may remain intact while enabling development of the land to proceed in a timely manner.

The proposed development could not occur until all native title issues over the Project Area are resolved. The preferred approach of Wesfarmers–Marubeni and the Water Corporation is to resolve all native title issues in relation to the Project Area by concluding an ILUA with the Miriung and Gajerrong people. This has been communicated by Wesfarmers–Marubeni and the Water Corporation to the Miriung and Gajerrong people and the Aboriginal representative bodies at all times throughout the consultation process.

Resolution of the native title issues by way of an ILUA is considered to be the most equitable way of securing access to land in the Project Area, and the most pragmatic approach to a timely resolution of the issues. Furthermore, negotiation of an ILUA, which satisfies the interests of the Miriung and Gajerrong people, may also result in the withdrawal of the ALRA claim over the portion of the Project Area located on the Spirit Hills pastoral lease.

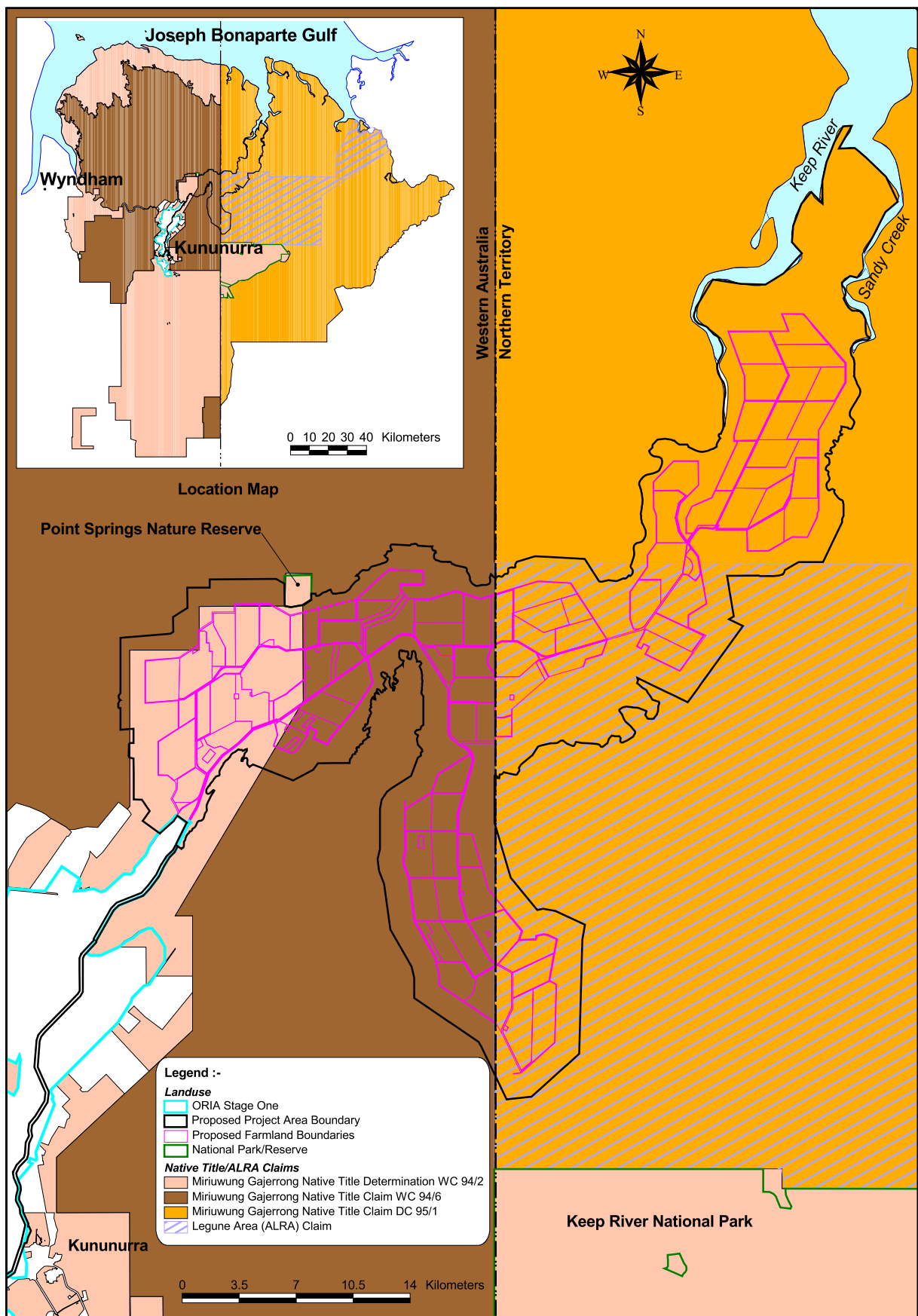


Figure 12.3 Native Title and land rights claims associated with the Project Area

The issues that the ILUA may address include compensation for the loss or temporary impairment of native title rights; management and protection of cultural heritage and environmental values; training and employment; establishment of business opportunities; and improving the social and economic development of Miriuwung and Gajerrong people

A spirit of co-operation has prevailed so far in discussions Wesfarmers–Marubeni and the Water Corporation have had with the Miriuwung and Gajerrong people and the Aboriginal representative bodies, which augers well for future discussions on substantive issues in relation to an ILUA. The spirit of co-operation has been evident in relation to work completed to date on cultural heritage (see Section 12.5) and Aboriginal social impact issues (see Section 12.6).

12.5 CULTURAL HERITAGE

12.5.1 Background

The Project Area is located within the traditional lands of the Miriuwung and Gajerrong people. Their traditional country broadly includes the land and seas adjacent to the Joseph Bonaparte Gulf, from the Ord River in the west to the Victoria River in the east (Mulvaney 1996, 3).

While no detailed ethnography of Miriuwung and Gajerrong people has been recorded, it is understood that Miriuwung country broadly includes the pastoral leases of Argyle, Ivanhoe, Newry, Spirit Hills and Rosewood. It is also understood that Gajerrong country occurs north and northeast of Miriuwung country, and broadly includes the pastoral leases of Carlton Hill, Legune, Spirit Hills and Bullo River. Miriuwung and Gajerrong people have strong social and cultural links to each other and to their lands (Mulvaney 1996).

Miriuwung and Gajerrong languages are related (Lee 1998, 66). Miriuwung and Gajerrong people believe that it is in their traditional lands where their languages belong (Lee 1998, 68) and that their language reflects the cultural knowledge that Miriuwung and Gajerrong people have of their country.

Miriuwung and Gajerrong country is criss-crossed by pathways or Dreaming tracks that the ancestral beings created in their journeys across the land during the ancestral epoch or Dreaming. Miriuwung and Gajerrong people refer to this period as the ‘Ngarranggarni’. Sites of cultural significance occur which include mythological sites, where Miriuwung and Gajerrong people attest that the ancestral beings conducted specific activities in the Dreaming. These sites are manifested in the form of geographic features and their associated vegetation including hills, waterholes, river systems and rock outcrops.

Specific cultural restrictions apply to access to certain sites. The travels and activities of the ancestral beings are recalled in song and ceremonies that continue to be practiced today by Miriuwung and Gajerrong people. Other places of cultural heritage significance reflect the prehistoric and contemporary use of the land by Miriuwung and Gajerrong people. Such places include middens, fish traps, stone arrangements, hearths, grinding hollows, paintings, engravings, burials, artefact scatters, stone quarries, ochre quarries and scarred trees, either singly, or in combination (Gregory 1994, 53).

There have been a number of cultural heritage assessments undertaken in the broader region both by independent consultants and by Government officers (Dortch 1977; Novak 1980;

Kirkby 1985; Quartermaine and O’Conner 1991; Quartermaine 1990; Barber et al. 1993; Gregory 1994; Gregory and Sutton 1997).

Archaeological excavations in the Ord River Valley at the Miriwun and Monsmont rock shelters, now under Lake Argyle in Western Australia, have resulted in the archaeological assemblages being dated to 17,980 BP (before present) (Dortch 1977). More recent archaeological investigations have revealed that the Jinmium rock shelter located east of the Project Area can be dated to the period 10–22,000 BP (Fullagar et al. 1996; Roberts et al. 1998).

Current cultural practices by Miriwung and Gajerrong people include the collection of red ochre from hills located on the coastal plains on the Legune pastoral lease, as well as other material for the production of artefacts. Ochre’s were, and still are, used in the production of paintings in the rock shelters in the immediate region (Mulvaney 1996). Aboriginal people assert a mythic origin for stone artefact material, which suggests that stone artefact scatters have a level of religious and historical significance (Barber et al. 1993).

To date, there has been no comprehensive ethnographic or archaeological assessment of the Western Australian portion of the Project Area, encompassing the Weaber Plain and the Western Australian portion of the Knox Creek Plain. However, there have been limited site-specific assessments conducted. There has been an ethnographic assessment (sacred site survey) of the Northern Territory portion of the proposed footprint of the irrigable land contained within the Keep River Plain and the Northern Territory portion of the Knox Creek Plain by the Aboriginal Areas Protection Authority (AAPA). Also, the Department of Lands, Planning and Environment Heritage Conservation Branch (HCB) have undertaken a comprehensive archaeological assessment of the same land within the Northern Territory.

12.5.2 Legislation relevant to Aboriginal cultural heritage in the Project Area

Cultural heritage sites are protected by State, Territory and Commonwealth legislation. The Project Area is affected by a range of cultural heritage legislation and Government processes, as well as by the desire of Miriwung and Gajerrong people to protect the cultural heritage values of their traditional land. Wesfarmers–Marubeni and the Water Corporation are obliged to comply with the following legislation relevant to cultural heritage matters:

- Commonwealth: *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (ATSIHPA), *Australian Heritage Commission Act 1975* (AHCA);
- Western Australia: *Aboriginal Heritage Act 1972* (AHA), *Heritage of Western Australia Act 1990* (HWAA);
- Northern Territory: *Northern Territory Aboriginal Sacred Sites Act 1989* (ASSANTA), *Heritage Conservation Act 1991* (HCA).

The overriding cultural heritage legislation is the ATSIHPA, the provisions of which are generally only invoked when the protection offered by the respective State or Territory legislation are deemed to be inadequate.

The AHCA is administered by the Australian Heritage Commission (AHC), a division of the Department of Environment Australia. The functions of the AHC are to identify and conserve the National Estate via the maintenance of the Register of the National Estate. The AHC has a particular interest in the conservation of Aboriginal cultural heritage values.

Under the Western Australian AHA administered by the Aboriginal Affairs Department (AAD), it is an offence to damage or destroy an Aboriginal site without the permission of the Minister for Aboriginal Affairs. Compliance with the AHA usually occurs via the commissioning of both an ethnographic and an archaeological assessment, involving the participation of Aboriginal people with a stated cultural heritage interest in the land. Qualified independent anthropologists and archaeologists generally undertake such assessments.

The HWAA provides for the identification and conservation of places of cultural heritage significance throughout Western Australia. The Heritage Council of Western Australia (HCWA) administers the HWAA and maintains the Register of Heritage Places that are considered to be worth conserving.

The Northern Territory ASSNTA is administered by the AAPA, and provides global protection for 'sacred sites' (ethnographic sites). It is an offence to damage or destroy a sacred site.

In order to comply with the provisions of the ASSNTA, proponents are obliged to apply to the AAPA to determine whether any sacred sites occur on the land subject to proposed development. The AAPA, after consultation with the relevant traditional custodians of sacred sites would then grant an Authority Certificate to the proponent, and the certificate would stipulate any conditions applicable to the proposed development and use of the land.

Under the Northern Territory HCA, it is an offence to damage or destroy an archaeological place without the permission of the Minister for Lands, Planning and the Environment. The HCB of the Department of Lands, Planning and Environment administers the HCA. As with the AHA in Western Australia, compliance with the provisions of the HCA occurs through the commissioning of an archaeological assessment. This assessment is generally undertaken by a qualified independent archaeologist, observing the advice of the HCB.

Should there be a need to disturb archaeological sites to enable a development to proceed, an application accompanied by the consultant's reports would be lodged with the HCB. The HCB administers the Heritage Advisory Council (HAC), which in turn provides advice to the Minister for Conservation regarding permission to undertake work on an archaeological place. The final decision on the matter rests with the Minister. As well as the necessity to comply with relevant State, Territory and Commonwealth legislation, including the Western Australian *Environmental Protection Act 1986*, it is critical that the aspirations of Miriuwung and Gajerrong people are adequately met as part of the proposed development. These aspirations were recently reinforced in the determination of native title for Miriuwung Gajerrong WC94/2 by Justice Lee of the Federal Court, who stated that Miriuwung and Gajerrong people have, amongst other rights:

a right to maintain and protect places of importance under traditional laws, customs and practices in the 'determination area'. (Lee 1998, 7)

12.5.3 Strategy for the protection of cultural heritage

Wesfarmers–Marubeni and the Water Corporation are committed to ensure compliance with relevant State, Territory and Commonwealth heritage legislation, as well as to meet the expectations of the Miriuwung and Gajerrong people in respect to the protection of cultural heritage. The approach to these issues is as follows:

- (a) to fully inform the responsible State, Territory and Commonwealth agencies responsible for cultural heritage legislation of the nature of the proposed development work;
- (b) to acquire information existing within the relevant State, Territory and Commonwealth agencies on the location, spatial dimensions and significance of known cultural heritage sites;
- (c) to establish and ensure implementation of a set of Cultural Heritage Protection Procedures to be observed by Wesfarmers–Marubeni and the Water Corporation, and all consultants and contractors, during the Project feasibility study and the future development of the Project;
- (d) to consult and negotiate with Miriuwung and Gajerrong people and their Aboriginal representative bodies as to how they wish to ensure that the cultural heritage values of the land are protected, and to undertake archaeological and ethnographic assessments of the Project Area;
- (e) to develop a Cultural Heritage Management Plan to ensure the long-term management and protection of the cultural heritage values of the land within the Project Area.

12.5.4 Cultural heritage assessments of the Project Area

In 1997, both the AAPA and the HCB undertook independent cultural heritage assessments of the proposed footprint of the irrigable land within the Northern Territory portion of the Project Area for the Northern Territory Department of Primary Industry and Fisheries (DPIF). These assessments resulted in the issuing of an AAPA Authority Certificate to the DPIF, and the production of a report on the archaeological sites located within the Northern Territory portion of the land by the HCB (see Section 12.5.5). This information has provided important baseline information for Wesfarmers–Marubeni and the Water Corporation with respect to the potential cultural heritage values of the entire Project Area.

In 1998 and 1999, Wesfarmers–Marubeni and the Water Corporation formally consulted the AAPA, HCB, AAD, HCWA and AHC with respect to the location, spatial dimensions and significance of known cultural heritage sites within the broader Project Area.

The AAPA formally issued Wesfarmers–Marubeni and the Water Corporation with an Authority Certificate over the land, which included details of sacred sites within and around the land. In addition, AAPA is in the process of issuing Wesfarmers–Marubeni and the Water Corporation with a further Authority Certificate to allow access to areas of land external to the Project Area to enable the potential removal of pavement material for roads and foundations.

The HCB has provided point grid references and physical descriptions of archaeological sites that were recorded during the 1997 assessment and documentation relevant to the assessment.

The AAD provided grid references for ‘Open Access’ Aboriginal sites (archaeological) occurring within a 1 km by 1 km polygon and ‘Closed Access’ Aboriginal sites (ethnographic) occurring within a 10 km by 10 km polygon within the Western Australian portion of the Project Area. No details on the spatial extent or significance of ethnographic sites were provided to Wesfarmers–Marubeni and the Water Corporation by the AAD.

The HCWA provided Wesfarmers–Marubeni and the Water Corporation with a list of places of cultural heritage significance within the broader region. None of the places listed occur within the Project Area or would be affected by the proposed development.

The AHC has advised that there are three cultural heritage sites in the immediate region of the Project Area – Morung Archaeological Site, Keep River Sites Complex and the Weaber Range Sites Complex - only the latter of the three sites is located in close proximity to the Project Area.

The available information on cultural heritage sites provided by the various Government agencies was overlaid on topographic plans of the Project Area. The proposed Project design, including the irrigation channels, drains and roads as well as the potential sugar-mill sites, was superimposed on the plans to ascertain whether any known cultural heritage sites would be affected by the initial design of the proposed development. This exercise revealed that five ethnographic sites would potentially be affected, and the proposed design was modified to ensure that these ethnographic sites would not be affected. The exercise also revealed that no known archaeological sites would be affected by the proposed development.

Access to information on known cultural heritage sites was crucial in order to ensure that sites would not be inadvertently impacted by future ground-disturbing activity, and that the proposed design could be readily altered at an early stage if necessary.

A reasonable prediction of ethnographic site distribution for the Western Australian portion of the Project Area could be made from the data on known ethnographic sites provided by the AAPA for the Northern Territory portion of the Project Area. These data revealed that the ethnographic sites in the Northern Territory portion of the Project Area, are primarily represented by specific hills, rock outcrops, water sources, and creek beds, banks and associated vegetation. These data also broadly suggest that the black-soil country encompassing the Keep River, Knox Creek and Weaber plains is of potentially low cultural heritage significance, notwithstanding that all of the land is of traditional significance to specific Miriuwung and Gajerrong people.

In keeping with the desires of the Miriuwung and Gajerrong people for cultural heritage information to remain confidential, information on known cultural heritage sites has not been disclosed in this ERMP/draft EIS.

12.5.5 Archaeological analysis

In 1997, an archaeological assessment of the Keep River Plain and the Northern Territory portion of the Knox Creek Plain were completed by the HCB (Gregory & Sutton 1997). The assessment was completed within the proposed footprint of the irrigable land on the two plains.

The assessment revealed that the distribution of archaeological sites within the Northern Territory portion of the land is *‘tightly defined in terms of their distribution and highly reliable predictions about this distribution can be made’*. The research classified the Northern Territory portion of the land into four ‘archaeological sensitivity classes’—low, moderate, high, and very high. The classification identified various land units as follows:

- *low* archaeological sensitivity; cracking clays, possibly containing extremely low levels of archaeological material.

- *moderate* archaeological sensitivity; cracking clays occurring near the margins of major streams, the Keep River and Sandy Creek, possibly containing some archaeological material of low density;
- *high* archaeological sensitivity; red-brown soils that are in a slightly elevated position within the landscape, containing stone artefact scatters that exhibit technological diversity and high densities; and
- *very high* archaeological sensitivity; prominent outcrops of sedimentary rock possibly containing a high density of stone artefact scatters, as well as rock shelters containing art and cultural deposits.

Tables 12.1 and 12.2 reflect the findings of the research and provide indicative proportions of the classes for the land within the Keep River Plain and the Northern Territory portion of the Knox Creek Plain (after Gregory and Sutton 1997, II).

Based upon the research of Gregory & Sutton (1997), a predictive model was developed by Wesfarmers–Marubeni and the Water Corporation for the archaeological site distribution within the proposed footprint of the irrigable land including the Weaber Plain portion of the Project Area. The model indicated that land units classified as having moderate archaeological sensitivity could be expected on 4% of the land. Land Units classified as high to very high archaeological sensitivity could also be expected on 4% of the land; however, this land would not be developed as it is unsuitable for agricultural purposes. The remaining 92% of the land could be expected to be of low archaeological significance and would be unlikely to contain significant archaeological sites. The predictive model was subsequently validated during an archaeological assessment undertaken in October 1998 (see Section 12.5.6).

Table 12.1 Proportion of the Keep River Plain by archaeological sensitivity class

Archaeological sensitivity class	Proportion
Low	96%
Moderate	2%
High	0%
Very High	2%
Total	100%

Table 12.2 Proportion of the Knox Creek Plain of each archaeological sensitivity class

Archaeological sensitivity class	Proportion
Low	96%
Moderate	1%
High	3%
Very High	0%
Total	100%

Two findings in the research of Gregory (1994) appear to be significant factors influencing the distribution of archaeological sites: the presence of water, and the apparent preference for uplands, not lowlands, for occupation purposes. There is a strong relationship between water and site location. In general, archaeological sites were found to be located most frequently at a distance less than 200 m from water and as the distance to water increased, so site frequency declined (Gregory 1994, 54). Also, the majority of previously recorded

archaeological sites tended to occur in the uplands; however, Gregory conceded that this distribution might reflect a previous research bias (Gregory 1994, 53).

As stated above, based upon the predictive model, only 4% of the land is likely to contain significant numbers of archaeological sites. It should be noted that most of the areas within which archaeological sites are likely to occur are associated with permanent watercourses and ephemeral creeks, and that these areas are unlikely to be impacted by the proposed development.

The predictive model, and known archaeological and ethnographic sites, was analysed in conjunction with the preliminary Project design layout. This process impacted the preliminary Project design layout in forty-nine locations. The preliminary Project design layout was revised so as to ensure that both known and predicted archaeological and ethnographic sites would be avoided by the proposed development.

The predictive model was also utilised by Wesfarmers–Marubeni and the Water Corporation in the development of a set of formal Cultural Heritage Protection Procedures (CHPP) (see Appendix N). The CHPP clearly outlines the protocol to be observed by representatives of Wesfarmers–Marubeni and the Water Corporation, and all consultants and contractors, with respect to the treatment of any archaeological sites and materials encountered during field work. The CHPP also details protocols to be observed in relation to ethnographic sites, interactions with Miriuwung and Gajerrong people, and various environmental protocols.

12.5.6 Cultural heritage fieldwork completed in 1998

Prior to 1998 there had been no comprehensive ethnographic or archaeological assessment of the Western Australian portion of the Project Area. Site specific assessments had occurred in the past. However, it is only in the Northern Territory portion of the land within the Project Area, that the AAPA and the HCB had completed an ethnographic assessment and an archaeological assessment respectively.

In mid 1998, Wesfarmers–Marubeni and the Water Corporation commenced discussions with the Aboriginal representative bodies; the ALS, KLC and the NLC; with respect to cultural heritage issues in relation to the entire Project Area. It should be noted that at that time, a single group did not represent the Miriuwung and Gajerrong people, but that the ALS, KLC and NLC collectively represented elements of the whole community. It should also be noted that the Miriuwung and Gajerrong people have to date yet to form a single representative entity. Wesfarmers–Marubeni and the Water Corporation throughout the community consultation process (Section 12.3 refers), conveyed the discussions with the Aboriginal representative bodies to the Miriuwung and Gajerrong people.

The objective of Wesfarmers–Marubeni and the Water Corporation was to have a single cultural heritage assessment completed of the entire Project Area completed by the latter part of the 1998 dry season. The objective was to have an assessment completed which would enable all proposed development works to proceed at some time in the future. It was also envisaged at that time that completion of the assessment would enable the completion of investigatory geotechnical works planned by Wesfarmers–Marubeni and the Water Corporation for October 1998.

Due to time constraints, a single cultural heritage assessment of the entire Project Area was not completed in the 1998 dry season. However, time permitted the completion of an assessment of cultural heritage issues with respect to the proposed investigatory geotechnical

works. The assessment was coordinated by the KLC and NLC, as a Work Programme Clearance.

The Work Programme Clearance was completed on:

- a 50m wide corridor of approximately 400 km length within which proposed irrigation channels, drains, levees and roads would be located;
- six potential sugar mill sites.

Fieldwork associated with the ethnographic component of the Work Programme Clearance was undertaken by twelve males and twenty-three female Miriung and Gajerrong people, who were accompanied by a male and female anthropologist respectively. The areas subject to the assessment were inspected by land and by helicopter (Figure 12.4).

Cultural information on ethnographic sites was not provided to Wesfarmers–Marubeni and the Water Corporation, but details were provided on locations within the assessment area where the proposed development may conflict with ethnographic sites. Furthermore, four of the six proposed sugar mill sites were considered to conflict with ethnographic sites (Barber and Rumley 1998).

As a result of the assessment, the proposed alignment of the M2 Channel adjacent to Cave Springs (Figure 12.5) has been re-designed, and four of the original potential sugar mill sites have not been subject to further consideration. It should be noted that these potential sugar mill sites are located off the black soil plains.

A secondary, yet important, outcome of the Work Programme Clearance was the validation of the central hypothesis of the predictive model—black soil cracking clay can generally be considered of minor cultural heritage significance, whilst hills, rocky outcrops and creeks can generally be considered to have cultural heritage significance to Miriung Gajerrong people.

Figure 12.4 Hillary Rumley and Miriung and Gajerrong people undertaking the Work Programme Clearance (photo courtesy Hillary Rumley)



Figure 12.5 Cave Springs



The investigatory geotechnical work was completed in October 1998, following completion of the ethnographic component of the Work Programme Clearance. The geotechnical investigation comprised the sampling and subsequent analysis of approximately one hundred and fifty drill holes and twenty-one backhoe pits. The backhoe and driver were sourced from the Waringarri Aboriginal Corporation in Kununurra (Figure 12.6).

Figure 12.6 Jack Trust, Waringarri machine operator during the 1998 geotechnical investigation work



Fieldwork associated with the archaeological component of the Work Programme Clearance was completed in conjunction with the investigatory geotechnical work. Two archaeologists, engaged by the NLC, surveyed the assessment area ahead of the geotechnical team to ensure that the investigatory works would affect no archaeological sites encountered.

Four additional archaeological sites and twenty isolated stone artefacts were identified during the assessment work, which lasted for nineteen days. Geotechnical works were deviated to avoid these areas of significance (Archae-Aus 1999).

The low incidence of archaeological sites and artefacts identified on the black soil plain conformed to the central hypothesis of the predictive model.

12.5.7 Further cultural heritage assessment

A further cultural heritage assessment would be required within and around the Project Area prior to the commencement of the proposed development. Assessment would be required for the proposed black-soil farmlands, the portion of the M2 channel linking the Kununurra Diversion Dam with the Project Area, as well as potential borrow pits for construction materials and communication sites. This assessment will ensure that Wesfarmers-Marubeni and the Water Corporation have fully complied with the relevant cultural heritage legislation, as well as the aspirations of the Miriuwung and Gajerrong people.

Negotiations between Wesfarmers-Marubeni and the Water Corporation, the Miriuwung and Gajerrong people and the Aboriginal representative bodies, are continuing with respect to the completion of the balance of the cultural heritage assessment. It is currently envisaged that this assessment will be completed during the 2000 dry season.

12.5.8 Managing cultural heritage

It is proposed that the findings of the combined cultural heritage assessments would support the development of a Cultural Heritage Management Plan (CHMP), which would define how the cultural heritage values within the Project Area would be protected and managed for the life of the Project.

The CHMP would reflect Wesfarmers-Marubeni and the Water Corporation's philosophy for the management of cultural heritage values in the Project Area. This philosophy includes:

- the establishment of field management techniques for the protection of surface and subsurface cultural heritage sites and materials;
- the development of an ideology of respect and value for cultural heritage sites and materials;
- the meaningful participation of Miriuwung and Gajerrong people in the CHMP during both the construction and the operational phases of the Project;
- the retention of the control and rights of cultural heritage knowledge by Miriuwung and Gajerrong people; and
- the use of appropriate expertise in the implementation of the CHMP.

The cultural heritage values that would need to be considered in the development of the CHMP include:

- all surface archaeological and ethnographic sites and cultural materials recorded during the cultural heritage assessments of the Project Area;

- all areas of land associated with the development and construction of the Project Area and associated infrastructure;
- all subsurface archaeological materials, including human remains, which may be discovered during excavation, grading or other earthworks during construction or operation; and
- all additional surface archaeological and ethnographic sites and cultural materials that may be identified during the post-construction phase or operation of the Project.

Wesfarmers–Marubeni and the Water Corporation intend to develop the CHMP in partnership with the Miriuwung and Gajerrong people. The CHMP would consolidate relevant information on cultural heritage sites and would detail mechanisms to ensure the harmonious coexistence of the cultural heritage values and the proposed development wherever possible.

Proposed measures, which would facilitate and ensure ongoing access of Miriuwung and Gajerrong people to cultural heritage sites, including traditional resource procurement zones such as the Keep River estuarine system, are as follows:

- the excision of significant cultural heritage sites from the Project Area;
- the establishment of ‘green access paths’ to cultural heritage sites located within the farmland, to guarantee ongoing access and foster the pursuit of traditional lifestyle practices;
- the establishment of the proposed 41,000 ha conservation area within the Project Area (Chapter 10 refers).

Particular significant cultural heritage sites, including Milligan Lagoon (Figure 12.7), Folly Rock and the hill adjacent to the Spirit Hills homestead, would be conserved within the 41,000 ha of proposed conservation area. These sites have a range of conservation values.

It is predicted that the development of the CHMP would detail and provide measures for mitigating any potential negative effect brought about by changes to the biological and physical environment of the black soil plains on the traditional cultural associations of the Miriuwung and Gajerrong people

Figure 12.7 View of Milligan Lagoon



12.6 ABORIGINAL SOCIAL IMPACT

12.6.1 Background

Over the last 25 years there have been a number of studies into the social and economic impact on Aboriginal people in the East Kimberley region as a result of pastoral, agricultural and mining development. Significant studies completed to date have been commissioned by the Kimberley Land Council and the State and Commonwealth Governments.

In 1978, the Commonwealth and Western Australian Governments jointly undertook a review of ORIA Stage 1 (Commonwealth of Australia 1978). The review examined, amongst other issues, the impact of the development on Aboriginal people. The review noted that the development of ORIA Stage 1 had '*contributed to the dislocation of the life and religion of Aboriginal people living in the area by destroying land of sacred and traditional value*' (ibid. 1978, 5).

The review also noted that Aboriginal people residing in Kununurra:

- were experiencing acute social problems, some of which could be identified specifically with the development of ORIA Stage 1;
- were experiencing lifestyle changes as a result of the flooding of Lake Argyle and the development of the irrigated land;
- had been displaced (approximately 250 people) from the pastoral leases by the land resumption's of the 1960s;
- had lost access or had access to country severely restricted as a result of land being resumed; and
- had lost sacred sites as a result of the inundation of Lake Argyle and the development of ORIA Stage 1, with the latter resulting in increased access by non-Aboriginal people to sites reducing or destroying their ceremonial significance.

During the period from 1985 to 1987, the Centre of Resource and Environmental Studies (CRES) at the Australian National University conducted extensive research in the East Kimberley on the social and economic impacts of the major resource developments occurring in the region at that time. These studies focused principally on the development of the Argyle Diamond Mine, and included aspects relating to ORIA Stage 1.

The CRES research found that Aboriginal people in the region had experienced a series of significant changes in the 1960s and early 1970s. These changes have included the introduction of equal wages, the increased reliance on capital intensive investment in the pastoral industry, and the establishment of ORIA Stage 1. All of the changes have led to some dislocation of Aboriginal communities and consequent social disruption (East Kimberley Impact Assessment Project 1985,2). A series of working papers and a final report were produced by Coombes et al. (1989) (*Land of promises—Aborigines and development in the East Kimberley*). The report noted that development should be planned so as to bring benefits to all of the people of the region, and must include Aboriginal people (Kimberley Land Council 1992).

In 1997, DRD commissioned AACM International Pty Ltd to undertake consultation with Aboriginal people regarding the potential development of ORIA Stage 2. This work was a component of an unpublished Public Environmental Review. The consultation with

Aboriginal people in 1997 revealed that the proposed development of ORIA Stage 2 would offer an opportunity for Aboriginal people to increase their participation in the regional economy and to reduce their dependence on resources from welfare programmes (AACM International Pty Ltd 1997, 3).

The consultation also identified various other potential impacts, including:

- the potential marginalisation of the Aboriginal community, resulting in the increased incidence of the symptoms of marginalisation such as alcohol abuse and family violence;
- potential increased pressure on existing health, education and other social services;
- potential non-participation of Aboriginal groups in the proposed development. Most Aboriginal people perceived that, without active participation and recognition, Aboriginal stakeholders would continue to become frustrated and depressed;
- potential restriction on access to plains and riversides for hunting, fishing and ceremonies;
- potentially harmful effects of chemicals on traditional foods and water supplies;
- improved access to currently remote areas. The development of the Project Area would result in improved access to the Knox Creek, Weaber and Keep River plains. Aboriginal people generally see this as a positive impact;
- potential increased incidence of water-related diseases. There was concern about the increased risk of diseases transmitted by mosquitoes, such as Ross River fever. Aboriginal people are especially vulnerable to diseases transmitted by mosquitoes because they often live and sleep outside and rarely have housing with screens; and
- possible pressure from construction crews. There may be a risk that construction crews may cause negative impacts on Aboriginal people as construction crews are typically made up of single, non-Aboriginal males.

The KLC has also noted potential economic opportunities for Aboriginal people in relation to the proposed development. In July 1998, over 300 people attended a conference, coordinated by the KLC, entitled 'The Kimberley—Our Place, Our Future'. In the conference proceedings, it was stated that *'major opportunities in the region include the expansion of tourism, the full development of the Ord River irrigation area, the expansion of pearling, and the development of a capacity to process meat'*.

In August 1999, the Western Australian Planning Commission released the draft 'Kununurra–Wyndham Area Development Strategy (KWADS) for public comment. The objective of KWADS is to develop and identify future land use and growth requirements of Kununurra and Wyndham (Section 1.2 refers). Preparation of KWADS included consultation with Aboriginal people and a workshop with Aboriginal people in Kununurra.

The KWADS research noted that:

- Aboriginal people are not well positioned to benefit from the range of employment, enterprise and lifestyle opportunities offered by an area preparing for substantial development;
- cultural and heritage issues require specialised consideration and the Aboriginal community require assistance to manage and strengthen their culture and heritage;

- homeland communities will require the coordination of responsibilities and actions of various planning agencies in order to realise community development aspirations;
- appropriate consultation procedures are necessary to involve the Aboriginal community and their representative bodies;
- opportunities need to be established to ensure Aboriginal participation in economic development and land management;
- land use agreements need to be considered to deliver benefits to Aboriginal people and to permit co-existence; and
- strategies need to be developed to encourage Aboriginal people to participate in and achieve economic and social benefit from the development of the region.

12.6.2 Framework for the process

Completion of an Aboriginal social impact assessment in relation to the proposed development is not a strict legal requirement for Wesfarmers–Marubeni and the Water Corporation. However, it is considered likely that completion of a Project-specific assessment would provide an invaluable insight into the social and economic expectations, and any concerns, held by Miriuwung and Gajerrong people in relation to the proposed development. As a consequence, it is likely that completion of an assessment would assist all parties in the negotiation and settlement of an ILUA.

Since January 1999, Wesfarmers–Marubeni and the Water Corporation have been working collaboratively with the Aboriginal representative bodies, who in turn have been working with the Miriuwung and Gajerrong people, to establish the terms of reference for the proposed assessment. The terms of reference are to outline the framework within which the information, regarding the potential impact that the proposed development may have on Aboriginal people, would be gathered, analyzed, documented and managed. The proposed terms of reference have been the subject of discussion at all of the Aboriginal community meetings convened by Wesfarmers–Marubeni and the Water Corporation in 1999. It has been agreed by the parties that the assessment is to be known as the Aboriginal Socio-Economic Impact Assessment (ASEIA).

The purpose of the assessment is to provide sufficient information about the proposed development to the Miriuwung and Gajerrong people to enable them to identify and assess any potential resultant impact. The objective of the ASEIA is to ensure that any potential impact from the proposed development is assessed with respect to:

- a Miriuwung and Gajerrong understanding of country, the use of land and access to culturally important areas and landscapes in and around the proposed development;
- any impact on the ability of Miriuwung and Gajerrong people to live in accordance with their own values, traditions and aspirations;
- any impact on community structures and vitality, and economic vitality;
- historical and current responses to previous developments in the region;
- the preferred outcomes of Miriuwung and Gajerrong people regarding the proposed development;

- maximising the potential positive impacts and the mitigation of any potential negative impacts.

The terms of reference for the ASEIA are in the process of being finalised with the Aboriginal representative bodies. Preliminary ASEIA research commenced in mid-June, with an anthropologist, an ethnobotanist and a land-use planner working with Miriuwung and Gajerrong people.

It is intended that the ASEIA will focus on three main areas of research as follows:

- ‘Planning for Country’: the output being an anthropological study and a land-use study;
- ‘Planning for People’: the output being a social research study;
- ‘Planning for the Future’: the output being an economic impact study.

Wesfarmers-Marubeni and the Water Corporation look forward to the completion of the ASEIA with the involvement and support of the Miriuwung and Gajerrong community.

13 Air quality and noise

This chapter addresses the impact the Project may have on air quality and noise in its environs, including smoke and ash from cane-burning and emissions from the sugar mill. The issue of greenhouse gas emissions is also addressed, both in terms of land development and ongoing operations.

13.1 REGIONAL METEOROLOGY

The Bureau of Meteorology collects meteorological data at Kununurra Airport. This site is about 30 km south-west of the closest areas of the Project Area and some 80 km from the furthest areas. Data from Kununurra Airport are shown in Tables 13.1 to 13.4, and provide percentage frequency distributions for wind direction and wind speed. Additional climatic data for Kununurra covering temperature, rainfall, relative humidity and evaporation parameters are shown in Table 13.5.

Table 13.1 Wind direction frequency distribution (% at 9 a.m.) at Kununurra Airport, 1986–98

Month	Wind direction								
	N	NE	E	SE	S	SW	W	NW	Calm
January	15	8	4	15	10	17	10	11	10
February	13	8	7	13	9	21	7	11	11
March	5	8	14	25	8	12	5	8	15
April	3	10	27	42	4	2	1	2	9
May	1	3	21	56	6	3	–	2	8
June	2	3	22	59	5	1	–	1	7
July	1	3	18	61	8	2	–	1	6
August	6	7	22	44	7	3	1	2	8
September	16	13	16	26	4	3	4	7	11
October	17	17	13	18	6	4	4	14	7
November	15	14	7	17	8	9	5	14	11
December	14	11	8	17	11	16	5	10	8

Note: Rounded to the nearest 1%. The gaps in the dataset from May, June and July indicate the range occurred but with a frequency distribution less than 0.5%.

Source: Bureau of Meteorology 1998.

Table 13.2 Wind direction frequency distribution (% at 3 p.m.) at Kununurra Airport, 1986–98

Month	Wind direction								
	N	NE	E	SE	S	SW	W	NW	Calm
January	15	13	6	19	9	9	5	16	8
February	16	7	11	13	8	12	6	17	10
March	9	15	21	24	8	5	3	5	10
April	6	12	30	32	7	2	1	2	8
May	4	8	19	48	9	2	–	3	7
June	4	6	16	49	13	2	–	4	6
July	7	5	19	47	12	2	1	2	5
August	13	8	10	36	11	4	1	7	10
September	24	15	7	20	12	3	3	9	7
October	26	13	7	15	10	4	2	15	8
November	22	15	11	10	6	5	4	20	7
December	21	16	8	13	7	6	6	15	8

Note: Rounded to the nearest 1%. The gaps in the dataset for May and June indicate the range occurred but with a frequency distribution less than 0.5%.

Source: Bureau of Meteorology 1998.

Table 13.3 Wind speed frequency distribution (% at 9 a.m.) at Kununurra Airport, 1986–98

Month	Wind speed (km/h)				
	Calm	1–10	11–20	21–30	> 30
January	10	63	24	2	1
February	12	63	22	3	–
March	16	60	20	4	–
April	10	43	32	14	1
May	7	31	36	24	2
June	6	39	25	28	2
July	5	34	30	28	3
August	8	36	28	25	3
September	10	43	33	12	2
October	8	45	35	11	1
November	11	54	32	3	–
December	9	61	27	3	–

Note: Rounded to the nearest 1%. The gaps in the dataset for February, March, November and December indicate the range occurred but with a frequency distribution less than 0.5%.

Source: Bureau of Meteorology 1998.

Table 13.4 Wind speed frequency distribution (% at 3 p.m.) at Kununurra Airport, 1986–98

Month	Wind speed (km/h)				
	Calm	1–10	11–20	21–30	> 30
January	8	50	32	9	1
February	11	47	33	9	–
March	9	43	38	8	2
April	8	39	44	8	1
May	5	45	43	6	1
June	6	45	40	8	1
July	5	43	44	8	–
August	10	42	39	8	1
September	8	43	42	6	1
October	6	35	43	13	3
November	6	40	33	14	7
December	8	42	37	10	2

Note: Rounded to the nearest 1%. The gaps in the dataset for February and July indicate the range occurred but with a frequency distribution less than 0.5%.

Source: Bureau of Meteorology 1998.

Table 13.5 Additional climatic data for Kununurra

Month	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Rainfall (mm)	Relative humidity (%)	Evaporation (mm)
January	36.0	24.4	190.5	65.0	230
February	35.0	24.2	201.9	68.5	176
March	35.5	23.4	114.8	60.6	195
April	35.1	20.7	44.1	44.3	217
May	32.7	17.9	12.0	36.2	212
June	30.5	15.3	3.2	35.7	203
July	30.5	14.1	6.5	31.9	209
August	32.9	15.5	0.6	32.5	241
September	35.8	19.0	3.6	34.2	294
October	38.0	22.8	23.3	39.0	330
November	38.9	24.5	63.7	47.7	287
December	37.8	24.8	123.8	55.8	275
Total	–	–	788.0	–	2,869

Source: Department of Resources Development 1996.

The wind data indicate a predominant daily east to south-east wind pattern between March and September. From September to February the easterly pattern declines and there is a greater influence of winds from the northern sector.

Morning (9 a.m.) wind speeds from April to October have an overall stronger pattern than at other times during the year. The afternoon (3 p.m.) data indicate a more uniform pattern throughout the year and have approximately equal percentage frequency distributions

between 1–10 km/h and 11–20 km/h. In the late part of the dry season (late October to early November) afternoon storms with strong northerly winds are a common occurrence.

It is likely that the Project Area has a similar meteorological pattern to that of Kununurra although there are potential microclimate variations due to several prominent topographical features, such as the Pincombe and Weaber ranges, that exist nearby.

13.2 DUST

Ambient levels of dust in the Project Area are likely to be highly seasonal, with low levels during the wet season, increasing during the dry season as the cover of native vegetation becomes substantially less and wind strength increases. Movements of vehicles on unsealed roads and stock movements would be localised sources of dust.

It is inevitable that dust would be generated during construction, predominantly from the earthworks associated with construction of farm blocks, service roads, irrigation channels and drains. Land-clearing and land-levelling in particular have the potential to generate dust due to the movement of vehicles on unsealed areas. The quantity of dust generated would depend to a minor extent on the moisture content of the ground surface during construction; however, all land development would be undertaken during the dry season as it would not be practicable to perform significant construction work on the clay soils of the Project Area during the wet season.

The bulk of the development work would be on the Weaber, Keep and Knox Plains, and the impact of dust on local residents from these construction activities would be mitigated by the remoteness of the Project Area. The M2 Channel, however, would be constructed adjacent to the existing M1 Channel from the Diversion Dam to the Project Area. The nearest permanent residences to construction activities associated with the proposed M2 Channel would be those on the outskirts of Kununurra, some 300 m away. These residences are located south of the M2 Channel alignment and, therefore, would be predominantly upwind of the construction activity.

The main issue associated with dust would be the protection of workers from excessive levels. Earth-moving contracts would be structured to require air-conditioned cabins on earth-moving equipment and monitoring of dust levels associated with development activities.

A dust monitoring programme would be established as part of the EMP and administered throughout the construction and operational phases of the Project, using dust deposit gauges that comply with AS 3580.10.1—1991. Periodic dust monitoring would also be undertaken using portable monitors.

13.3 SMOKE AND ASH

13.3.1 Cane-burning

The burning of sugar cane in preparation for harvesting is an integral part of farming operations for the majority of cane-growers worldwide. Sugar cane grows vigorously in the Ord region, and the burning of cane facilitates efficient harvesting. Burning also has a number of beneficial effects on cane-farming operations: these include reducing the amount

of trash (unwanted leaf material) delivered to the sugar mill and reducing the levels of pests in the cane fields. Cane fires are fast and hot and create a strong updraught.

Typically, a cane fire lasts for about five minutes as only sufficient sugarcane for the next day's harvest is burnt and the fallout of ash particles may last for a further fifteen minutes, depending upon local meteorological conditions. The updraught created by the fires ensures that there is little smoke at ground level. Furthermore, having regular fires within the Project Area would not be a new occurrence. It is understood fire stick farming practices have been used in Northern Australia by Aboriginal people for many years (Langton 1998).

If the cane was not burnt prior to harvesting much of the trash would be left on the farm. Harvesting of cane which has not been burnt beforehand is known as green cane harvesting. Rapid removal of the trash, to facilitate irrigation of the ratoon crop or replanting of sugarcane, would be required.

A number of issues have arisen with respect to cane-burning when it occurs near populated areas, and in some locations increasing pressure from Government and the public has seen restrictions developed on burning practices. In other areas burning has been eliminated and green-cane harvesting techniques developed. In 1997 it was estimated that over 60% of Queensland cane-growers used green-cane harvesting techniques. However, in the Burdekin district of Queensland, which has similar cane yields and irrigation systems to ORIA Stage 1, less than 5% of the crop in 1997 was harvested using green-cane techniques. A summary of the positive and negative aspects associated with cane-burning is presented in Table 13.6.

Table 13.6 Summary of positive and negative aspects associated with cane-burning

Positive aspects	Negative aspects
Reduces the amount of trash delivered to the mill.	Generates smoke and cane ash fallout ('black snow'), which is a general nuisance in populated areas, particularly affecting laundry on washing lines and swimming pools.
Controls vermin.	
Reduces cane trash within furrows that can obstruct flood irrigation.	Reduces soil cover and increases risk of erosion during heavy rainfall events.
Leads to rapid incorporation of some of the nutrients within cane ash into the soil.	Results in loss of organic matter and some trace elements to the atmosphere.
If managed properly, it can reduce the risk of uncontrolled fires spreading through large areas and potentially adversely affecting the crop, operations and safety.	If not managed properly, it provides an opportunity for fire to spread to surrounding bushland areas or cane paddocks at times when burning is not required or desirable.

Existing growers in ORIA Stage One have adopted cane-burning prior to harvest, and this practice occurs throughout the period between April and September. Occasional complaints associated with smoke and cane ash fallout have been lodged with local government regulatory agencies. Changing production practices to green-cane harvesting in ORIA Stage One has been investigated in the past and not adopted. The main reason for green-cane harvesting not being adopted is concern that the additional trash generated during harvesting would interfere with flood irrigation of the cane fields. For this reason cane-burning is considered the preferred method of cane-harvesting for the Project at this time.

Another reason for the adoption of cane-burning as the preferred method of cane-harvesting is that the remoteness of the Project Area, some 30–80 km north-east of Kununurra, would

effectively eliminate land-use conflicts associated with the practice. In addition, meteorological data (Tables 13.1 and 13.2) indicate wind directions for the Kununurra region are predominantly south-east and east for the greater period of the year, particularly during the period of April to October when the sugarcane would be harvested. Consequently, smoke and cane ash would be dispersed away from population areas for most of the harvesting period.

Despite there being a low potential for nuisance issues associated with cane-burning, green-cane harvesting techniques would be investigated as part of the Project's ongoing research programmes into cane cultivation in the ORIA. This research would also assess any other environmental benefits of green-cane harvesting, such as reductions in greenhouse gas emissions. The issue of greenhouse gas emissions is discussed in Section 13.5.

13.3.2 Land-clearing impacts and their management

Some smoke and ash may be generated from burning wood and other vegetation during the construction phase of the Project. The impact of this activity is anticipated to be minimal and temporary as the burning would be carried out over a relatively short period. The isolation of the Project Area and the relatively sparse coverage of vegetation on the black-soil plains also reduce the significance of this issue. Furthermore, burning practices would be managed to occur at times when prevailing winds would direct smoke and ash away from any residential areas.

13.4 EMISSIONS FROM THE SUGAR MILL

The sugar mill would primarily be powered by burning bagasse in a boiler, with stand-by power being supplied either from local generating capacity or from the Western Power grid. Emissions to the atmosphere would occur from the following sources at the sugar mill:

- the boiler chimney;
- the cooling towers and steam safety valves;
- intermittent use of a diesel generator.

Boiler chimney

Approximately 200 t/a of bagasse would be consumed in the sugar mill boilers to produce the steam for process purposes and to generate power. Two fuels would be used in the boiler: bagasse during normal operations, and fuel-oil at start-up. The boiler would usually operate continuously during the crop harvesting season.

The gas volume discharged by the chimney would be 420 m³/s at 45°C and it would have a density of 0.83 kg/m³. Prior to discharge, the gases would be passed through a scrubber to reduce particulate levels to fewer than 0.12 g/Nm³, a level which is well within the current national guideline value of 0.25 g/Nm³ for control of air pollutant emissions from new stationary sources (Australian Environment Council and National Health and Medical Research Council 1986).

Bagasse firing would be maintained as a complete combustion process with excess oxygen at all times; therefore, only insignificant levels of carbon monoxide would be generated.

Fuel-oil use would be necessary only during boiler start-up conditions, and about 20 t/h would be consumed. The fuel-oil would typically contain 0.7% sulphur, and the emissions from the chimney during the use of fuel-oil are expected to contain 300 ppm of sulphur dioxide, 200 ppm of oxides of nitrogen and fewer than 200 mg/Nm³ of carbon monoxide.

Cooling towers and steam safety valves

Water vapour would be given off continuously by cooling towers and occasionally by steam safety valves.

The steam would be discharged at temperatures ranging from 120°C to 400°C.

13.5 GREENHOUSE GAS EMISSIONS

13.5.1 Background

The Commonwealth Government, through the Greenhouse Office and Greenhouse Challenge Co-operative Agreements, provides encouragement for the reduction of greenhouse gas emissions by industry. Further strategy initiatives, such as emission offsets against known greenhouse sinks and emissions trading, are evolving from the recent international greenhouse conference at Kyoto in 1997. These initiatives are still in their formative development stages nationally and internationally.

At Kyoto, Australia was successful in gaining acceptance for differentiated commitments to climate change targets. The agreement that was reached will allow Australia to have an 8% rise in emissions above 1990 levels by 2008–12. The Protocol from the Kyoto conference also allows all the main greenhouse gases from all sectors to be included. This means that rising emissions from energy use can be offset, to some extent, by a fall in emissions from changed land uses.

The Kyoto Protocol was opened for signature by Parties to the Conference in mid-March 1998. However, ratification and the subsequent entry into force of the Protocol's conditions are expected to take at least several years.

Perhaps the most important implication of the Kyoto Protocol for Governments at all levels and the community is that, within a few years, and for the first time in history, Australia is likely to be subject to a legally binding target that may impact directly on domestic economic activity—a target that Australians should assume is going to be enforced (Barrett 1998).

Australia's efforts to address the greenhouse issue effectively commenced in 1992 with the National Greenhouse Response Strategy. This was adopted by Australian Governments as the framework for policies covering all sources and sinks of greenhouse gases across all sectors of the economy. Since then, measures with major greenhouse-gas-reducing potential have been implemented across most sectors of the economy. They include energy market reforms, a number of initiatives aimed at increasing the efficiency of energy use by industry and domestic consumers, and large-scale tree planting and revegetation programmes (Barrett 1998).

The Commonwealth Government published another strategy dealing with greenhouse gas issues, the National Greenhouse Strategy, in 1998 after it was endorsed by the Council of Australian Governments. It had previously been released as a discussion paper.

Objectives of the National Greenhouse Strategy include improving the cost-effectiveness, competitiveness and availability of energy technologies that abate greenhouse emissions, and increasing energy use efficiency and the adoption of ‘greenhouse-friendly’ behaviour, practices, technologies and fuels. In the vegetation and forest management sector, proposed strategies include reducing land-clearing and encouraging the increased capacity to sequester greenhouse gases through forest planting; and in the agricultural sector, the strategies include reducing fuel use and improving a range of farm management practices.

The EPA has also developed a greenhouse gas emission policy for new projects requiring environmental impact assessment. This policy requires proponents to indicate their projects’ greenhouse gas emissions inventory and to implement measures to minimise their project’s impact on the environment.

The sugar industry as practised in Australia and internationally has both greenhouse gas sources and carbon sinks. A summary of potential sources and sinks for the Project is presented in Table 13.7. In addition, the Project has the potential to displace or reduce existing greenhouse gas sources (e.g. through removal of cattle from the Project Area).

Table 13.7 Potential sources of greenhouse gases and carbon sinks for the Project

Potential sources of greenhouse gases	Potential carbon sinks
Burning of vegetation during construction.	Reduced burning of the Project conservation area by adoption of improved fire management techniques.
Sugarcane and soils release carbon dioxide and nitrous oxide.	Uptake of carbon dioxide by sugarcane.
Burning of sugarcane prior to harvest produces carbon dioxide, nitrous oxide and methane.	Increase in organic content of soils.
Fuel usage at the sugar mill (burning of bagasse) and farm machinery.	Carbon contained in products (raw sugar and molasses) stored.
Fuel usage during transport.	

13.5.2 Effects of initial development

Project development would entail removal of approximately 36,000 ha of the existing vegetation cover of grass and sparse trees and replacement of much of that area with agricultural farmland. The principal crop would be sugarcane, a perennial grass that would be grown on most of the farm area. The amount of carbon stored in the Project Area in both the existing and developed scenarios would vary seasonally. The comparison of the two scenarios shown in Table 13.8 is therefore made on the basis of the minimum carbon stored at any time, which corresponds to the end of the dry season for both scenarios. The comparison ignores carbon stored in vegetation that would not be cleared and carbon stored in the soil. These factors are assumed not to change significantly over the short construction period planned for the Project.

Table 13.8 shows that the minimum carbon stored would increase following project development, from about 19,500 t currently to about 670,000 t at full development. Most of this increase is from the growth of sugarcane (including roots, trash and tops) during the dry season following progressive harvesting of the crop, and the estimate includes the effects of burning prior to harvest. It also includes the carbon content in the raw sugar and molasses that would be in storage at the end of the dry season.

Table 13.8 Minimum total carbon stored in the Project Area for the existing and development scenarios *

Existing scenario**		Development scenario _L	
Sink	Stored carbon (t)	Sink	Stored carbon (t)
Trees	1,500	Cane roots	180,000
Grasses and litter	18,000	Cane	210,000
		Cane trash	58,000
		Cane tops	124,000
		Sugar storage	79,000
		Molasses storage	19,000
Total	19,500		670,000

* Does not include carbon stored in soils and in vegetation in areas that would not be cleared.

** Assumes full grass cover.

_L Assumes 50% of independent farms planted to sugarcane with balance to annual crops.

Project development would be beneficial in reducing the level of carbon dioxide (a greenhouse gas) in the atmosphere by sequestering it in ongoing carbon storage. This reduction, although not significant on a global scale, would be consistent with Australia's commitments under the Kyoto Protocol (Section 13.5.1).

The calculations supporting the data in Table 13.8 require a number of assumptions to be made. These assumptions, and their supporting references where applicable, are described below.

The total amount of carbon stored in the existing scenario was calculated based on the data and methods used in Howden et al. (1994) and assumed the percentage of carbon contained in dry plant matter to be 45% (Chapman et al. 1992). A figure of 1,000 kg/ha was used for the dry mass of existing grasses and litter, typical of the vegetation in the Project Area, from a study of a similar environment in north Queensland (Howden et al. 1994). Roots were assumed to be 15% additional to this. None of the Project Area was assumed to be burnt for the existing scenario, although fires are quite common in the region throughout the dry season. The carbon contained in livestock was considered too small to include in calculations.

For the development scenario the total quantities of carbon stored in the roots, cane, cane trash and cane tops were calculated as follows: 61% cane, 9% cane tops, 17% cane trash and 13% roots (Chapman et al. 1992). The carbon stored in the roots was assumed to be unaffected by burning and harvesting. Cane trash was assumed to grow in proportion to the cane, with both starting from the value zero at the time of harvest and growing uniformly throughout the year. The carbon stored in the cane tops was assumed to be a full year's growth, as cane tops would be discarded to the cane field during harvest.

13.5.3 Effects of ongoing operations

The previous section examined the implications of the Project on the level of stored carbon by comparing the scenario immediately after full development with the existing situation. This section examines the relative contributions of various greenhouse gas sources and carbon sinks during ongoing operations.

The results of calculations into the estimated greenhouse gas balance for the project operations, summarised in Table 13.9, show that development of the Project would result in a net reduction in greenhouse gas emissions from the Project Area each year. It is estimated that the magnitude of this reduction would be approximately 160,000 t/a of carbon dioxide equivalent carbon.

Table 13.9 Estimated greenhouse gas balance during project operations

Source/sink	Description	Greenhouse gases as carbon dioxide equivalent carbon* (t/a)			
		Carbon dioxide	Nitrous oxide	Methane	Total
Farmland	Destocking (removal of cattle)**			-300	-300
	Biological processes in crop and soil	128,800	40,800		169,600
	Crop burning	173,200	102,200	6,600	282,000
	Crop growth	-1,193,400			-1,193,400
	Assimilation of organic carbon in soils	-32,000			-32,000
Sugar mill	Bagasse and fuel oil	603,700			603,700
Machinery	On-farm (cultivation)	2,400			2,400
	Harvest	2,500			2,500
	Cane transport	1,000			1,000
	Sugar and molasses transport	1,600			1,600
Total		-312,200	143,000	6,300	-162,900

* Using global warming potential of carbon dioxide = 1; nitrous oxide = 310; methane = 21.

** Shown as methane but actually a mixture of all gases, with global warming potential used by the data source for this item of carbon dioxide = 1; nitrous oxide = 270; methane = 11.

Note: Negative values indicate sinks.

It should be noted that Table 13.9 excludes greenhouse gas emissions that would arise from consumption of the raw sugar and molasses products and the fuel required to transport the products to markets, principally in Asia, from Wyndham. The assumption made is that the Project would only displace demand for the products that would be satisfied by other producers if the Project did not proceed. Hence the carbon contained in the products, approximately 236,000 t/a, nor the greenhouse gas emissions of their transport were considered in the greenhouse gas balance for the Project.

Greenhouse gas emissions from shipping and transport would also occur with respect to alternative sources of supply should the Project not proceed. However, in the case of shipping and transport, the Project would in all likelihood displace existing sugar suppliers that have greater shipping distances to the intended markets. It is estimated that a net reduction of up to approximately 40,000 t/a may result from shipping of the products due to development of the Project. This would be on the basis that future demand would be satisfied in proportion to current exports to Asia from existing producers.

The greenhouse gas emissions from the existing pastoral activities were calculated using the values reported in Howden et al. (1994), who studied a similar scenario in northern Queensland. Greenhouse gas emissions and assimilation from sugarcane production were calculated from the values provided in Weier (1998), utilising mean values from the Australian sugar industry wherever a range of values was quoted.

The calculations also assume that the level of organic carbon in the surface 150 mm of soil would increase under irrigated cultivation of sugarcane from the current level of about 0.4% (Table 4.2) to a level of 1.5% over a period of twenty years. A level of 1.5% organic carbon is the minimum level preferred for optimal crop growth (Table 4.3) and it would therefore be the target level for farm managers.

13.6 NOISE

The Project Area is currently characterised by a general absence of development and low ambient noise levels typical of isolated rural areas. The dominant sources of noise would include rustling of vegetation and insects. Periodic sources of noise would be associated with the low-intensity rural operations and consist of vehicle movements (e.g. cars, helicopters, motorcycles) and animal noises (e.g. cattle lowing). Closer to Kununurra, ambient noise levels are higher, particularly in proximity to major roads, and centres of commercial and industrial activity.

Noise would be generated during construction from large earth-moving machinery associated with earthworks, land-clearing and levelling. Noise would also be generated at construction sites (e.g. at the sugar mill) and from vehicle movements. The main noise-generating activity of the Project would occur at distances of 30–80 km from Kununurra and, under these circumstances, would have negligible effect on existing residences.

Construction works associated with development of the M2 Channel may at times be within 300 m of existing residences. The following management measures would be adopted to mitigate adverse impacts on these residences:

- construction activities would be restricted to daylight hours for all activities within 500 m of an existing residence;
- all occupiers of residences within 1 km of construction activities would be advised of the nature and duration of the activities planned, and well in advance of construction commencing;
- all construction equipment would be fitted with appropriate silencing equipment and operated in a manner such that the construction activities comply with the Environmental Protection (Noise) Regulations (as amended) published by the EPA in October 1997.

Noise would be generated from operational activities associated with the farms and the sugar mill in the Project Area. However, negligible impact on existing residences is foreseen due to the relative remoteness of the Project Area from built up areas.

Transport of the products (raw sugar and molasses) from the sugar mill to Wyndham would occur on a twenty-four hour basis during the dry season. Approximately forty-five vehicle movements per day are anticipated. The only transport route available at present skirts the township of Kununurra and through Wyndham. All trucks used for product transport would be fitted with mufflers such that noise levels conform to noise abatement regulations.

14 Public health

This chapter outlines the public health issues associated with the proposed development and the management measures proposed to mitigate potential adverse impacts. The two main issues are mosquito borne diseases that occur in the East Kimberley and farm chemicals in the environment.

14.1 MOSQUITO-BORNE DISEASES

14.1.1 Background

Ecological changes brought about by dam construction and irrigation area development in tropical regions around the world have been shown to be associated with an increased incidence of diseases such as malaria, filariasis, schistosomiasis, and those caused by arboviruses (Stanley 1972). Of these the most important to human health in north-west Australia are the arboviruses (Mackenzie and Broom 1999).

More than sixty-five arboviruses have been isolated in tropical Australia. Relatively few are human pathogens, and even fewer are of major concern. The viruses that cause, or have caused, significant human disease in Australia are the flaviviruses, dengue viruses and alphavirus groups (Mackenzie 1998). The significant viruses that occur within these groups are presented in Table 14.1.

Table 14.1 Significant arbovirus groups in Australia

Arbovirus group	Virus name
Flaviviruses	Murray Valley encephalitis virus, Kunjin virus and Japanese encephalitis virus
Dengue viruses	Virus types 1, 2 and 3
Alphaviruses	Ross River virus and Barmah forest virus

The flavivirus, which causes Murray Valley encephalitis, and the alphavirus, which causes Ross River virus, are the two most important pathogenic arboviruses causing human disease in Australia. Both are enzootic (always present) in the east Kimberley. Barmah forest virus has also been recorded in the Ord River area. The mosquito *Culex annulirostris* is an important vector of both the Murray Valley encephalitis virus and the Ross River virus. *Culex annulirostris* breeds in fresh water and is the predominant species of mosquito found in the Ord River area.

Murray Valley encephalitis virus

Epidemics of Murray Valley encephalitis occurred in eastern Australia between 1917 and 1925; over 280 cases were reported with a fatality rate of 68%. The most recent epidemic

occurred in 1974, at which time the disease was renamed Australian encephalitis. Since 1974 all reported cases of Australian encephalitis have been confined to northern, and particularly north-western, Australia. The Kimberley region of Western Australia contains the only known confirmed enzootic foci of Murray Valley encephalitis virus activity (Mackenzie and Broom 1999).

Australian encephalitis is potentially fatal. The Murray Valley encephalitis virus is recognised as the main aetiological agent of Australian encephalitis, although a few cases are caused by the closely related Kunjin virus (Mackenzie and Broom 1999). There appears to be a correlation between the occurrence of the virus and the density of waterbirds and the predominant mosquito *Culex annulirostris*. Early studies investigating the ecology of the virus demonstrated that mosquito density and bird numbers had increased since the establishment of ORIA Stage One (Stanley 1972).

Increasing numbers of Australian encephalitis cases have occurred in Western Australia and the Northern Territory since 1977. Of the cases reported in Australia since 1977, thirty of the forty-eight have been from Western Australia, with a further thirteen from the Northern Territory. Many of the cases in Western Australia have occurred in areas distant from the Ord River, and of particular significance was the occasional spread of Murray Valley encephalitis virus from the Kimberley to the Pilbara and Gascoyne regions. It is hypothesised that the movement to the Pilbara was due to increased viral activity following heavy rainfall and the movement of waterbirds (Mackenzie and Broom 1999).

Ross River virus

The disease caused by Ross River virus is much more common than Australian encephalitis. Although it is debilitating, it is fortunately not fatal to its victims. However, the symptoms can persist for many months or even years. Ross River virus is one of the most frequently isolated arboviruses in Australia and has been obtained from more than thirty species of mosquito in six genera. Recently, the north-east Kimberley region was identified as having the highest case attack rate of Ross River virus in Australia (Broom and Lindsay 1998).

The average number of cases that have been reported nationally each year is approximately 4,800, with a maximum of 7,802 in 1996 and minimum of 2,602 in 1995 (Mackenzie 1998).

Recent research findings of Ross River virus in male mosquitos of the genus *Aedes* suggest vertical transmission to subsequent generations of mosquito via desiccation-resistant eggs. This provides a mechanism by which the virus can persist for long periods in the environment and would explain the rapid onset of cases following heavy cyclonic rainfall and flooding in arid regions. Recent evidence suggests that mammals such as western grey kangaroos and horses are the major vertebrate hosts and that birds are not involved in Ross River virus ecology. However, arbovirus transmission cycles are complex and relatively poorly understood in Australia (Mackenzie 1998).

14.1.2 Monitoring for mosquito-borne diseases

Since 1972 the Arbovirus Surveillance Laboratory at the University of Western Australia has been monitoring mosquito populations in the Kimberley region. These field sampling studies have become increasingly important as Australian encephalitis cases have become more frequent. Improved mosquito collection practices have been developed during these

studies together with a more effective surveillance system to provide an early warning of increased virus activity.

In 1981 a sentinel chicken surveillance flock was established and by 1989 the number of flocks had increased to twenty-four in twenty-two regional centres in the Kimberley, Pilbara and Gascoyne. Similar sentinel programmes were established in 1992 in the Northern Territory. These programmes have shown that Murray Valley encephalitis virus is enzootic in several areas of the Kimberley, particularly in the Ord River area at Kununurra (Broom et al. 1998; Aldred et al. 1992; Mackenzie et al. 1992).

Since 1978, mosquito trapping has been undertaken in the east Kimberley at the end of each wet season. The results of this trapping show that, regardless of the area, *Culex annulirostris* dominates after widespread rain and flooding. Other floodplain-breeding species such as *Aedes normanensis* may dominate initially if rainfall is more localised. The numbers of mosquitoes vary widely from year to year but the highest numbers correspond to years with heavy wet season rainfall (Broom et al. 1995).

The Murray Valley encephalitis virus has been isolated every year in significant numbers of adult mosquitoes and there is a strong correlation between the number of virus isolates in any given year and the prevailing environmental conditions. Although most Murray Valley encephalitis virus isolates were obtained from *Culex annulirostris* mosquitoes, occasional isolates were also obtained from a variety of other species.

Researchers derived the following conclusions from the circumstantial evidence provided by the results of monitoring conducted to date in and around Kununurra:

- Damming of the Ord River and development of ORIA Stage One has attracted increased waterbird populations and provide additional mosquito-breeding habitats that would be conducive to increased arbovirus activity (Stanley 1972; Mackenzie and Broom 1999).
- More *Culex annulirostris* mosquitoes are present within the irrigation area at the end of the dry season than in the surrounding areas.
- Virus activity usually occurs in the Ord River region before activity elsewhere in the Kimberley.
- Results from studies at locations in the Kimberley such as Billiluna and Halls Creek suggest that Murray Valley encephalitis virus is epizootic (temporarily prevalent) in many areas of the Kimberley. It is also likely that the virus was also epizootic in and around Kununurra prior to the development of ORIA Stage One (Mackenzie and Broom 1999).
- The development of ORIA Stage One has created conditions suitable for other exotic arboviruses such as Japanese encephalitis virus, and chikungunya virus and exotic mosquito vectors such as *Aedes albopictus* (Mackenzie and Broom 1999).

14.1.3 Management of impacts related to the Project

Management action would be taken in conjunction with the proposed development to reduce the risk of increased infection with arboviruses. These actions would concentrate upon the following activities:

- designing and operating the Project so as to reduce the potential for increased mosquito-breeding activity;

- implementing education programmes for the Project's construction and operational workforce on measures that could be taken to reduce their personal risk of infection;
- extending the existing monitoring programmes to cover the Project Area.

Design and operational features

A number of design and operational features would be incorporated into the Project that would either directly or indirectly reduce the potential for increased mosquito-breeding activity. These features would include the following:

- removing surface undulations (gilgai), laser levelling of farm units, and providing formalised drainage to large areas of black-soil plains that are currently inundated during the wet season. These measures should substantially reduce the number of natural mosquito-breeding areas within the Project Area;
- through design, ensuring that irrigation water supply channels are swift-flowing and that balancing storage dams are through-flowing to avoid areas of 'still' water;
- through the provision of an automated control system for the irrigation infrastructure, maintaining water levels in the irrigation channels over a narrow operating range, thereby avoiding periodic wetting of channel banks and the consequential formation of breeding habitat for some species of mosquito;
- maintaining the irrigation channels regularly and regulating storages to remove weeds that may be conducive to mosquito breeding;
- operating the irrigation tailwater return systems so that the tailwater storage dams are normally empty.

Education programmes

Education programmes would be developed to advise the Project's construction and operational workforce and their families on measures they can take to reduce their risk of infection by arboviruses. The education programme would commence as part of the induction training provided to all new employees and would continue with ongoing awareness training.

The education programme would include the following:

- background information on the sentinel chicken programmes run in Western Australia and the Northern Territory and interpretation of the information made public from these programmes, including warnings of high arbovirus activity in the region;
- information on measures that can be undertaken to reduce the incidence of mosquito bites, including the wearing of appropriate clothing, the use of insect repellants and the reducing of outdoor activities at early morning and at dusk when mosquito activity is at its highest;
- an awareness programme that would enable employees to identify potential mosquito-breeding areas within the Project Area and to bring these to the attention of management so that remedial measures could be investigated.

Monitoring programmes

Monitoring of mosquitoes within the Project Area would be a component of the EMP that would be developed for the Project. At this stage it is anticipated that this would involve an extension of the surveillance monitoring programme currently undertaken in Kununurra. This would involve:

- sampling immediately after the first wet-season rains to investigate the activity of viruses in the region;
- monitoring mosquito fauna and virus-carrying rates in different years and at different times of the year;
- surveys of a range of mosquito and vertebrate host habitats;
- surveys of breeding patterns and density of vertebrate hosts, and monitoring infection rates of these hosts with viruses;
- conducting surveys of mosquito larvae in newly constructed irrigation areas.

14.2 FARM CHEMICALS IN THE ENVIRONMENT

14.2.1 Overview

The development of modern farming practices around the world has been associated with an increased use of agricultural chemicals. In some instances the use of farm chemicals has led to conflicts with adjacent land users, particularly if there have been any concerns regarding possible health effects on the surrounding community from repeated exposure to these chemicals.

The public health issues associated with the use of agricultural chemicals in the Project Area would be mitigated by the lack of other intensive land uses nearby and by the dominance of sugarcane cultivation, which has minimal chemical requirements for successful growth. However, a number of management measures are proposed to manage the issue of farm chemicals and the environment, as discussed in the following sections.

14.2.2 Commonwealth, State and Territory controls

All chemicals that would be used within the Project Area are controlled by Commonwealth, State and Territory regulatory mechanisms. The Commonwealth role essentially consists of legislative controls to regulate the chemicals that can be used within the Commonwealth, and the preparation of material handling requirements and guidelines. The State and Territory roles consist of controls over chemical use, the setting of policy and the monitoring of standards (Schofield and Simpson 1996).

Commonwealth management measures

Perhaps the most significant Commonwealth role is that played by the NRA, which restricts and registers the use of chemicals within the Commonwealth and ensures that appropriate user instructions are available. The NRA is an independent statutory body which was established to ensure that chemicals are safe (e.g. with no unacceptable risks to humans, animals, the environment and trade with other nations) and effective when used according to

the label directions. The primary functions of the NRA can be summarised as assessing, reviewing and registering chemical products (and their active ingredients) for use in Australia (Schofield and Simpson 1996).

The NRA's activities are undertaken through three programmes that allow it to conduct special reviews of specific concern, reduce the likelihood of chemicals adversely affecting trade, and ensure that currently registered chemicals continue to meet the necessary standards of safety and performance. These programmes are as follows:

- Ad Hoc Review Program
- Regulatory Review Program
- Existing Chemicals Review Program.

Environment Australia works with the NRA by conducting environmental hazard assessments of chemicals. Manufacturers provide information on the chemicals, and this is combined with data from other sources to establish the degree of environmental exposure, the toxicity of the chemical to flora and fauna, and the overall environmental hazard posed by the chemical. The EPA (Commonwealth) may also request additional data, trials, controls, label instructions and warnings to minimise the environmental risk of chemicals.

An example of the NRA's role in the management of chemical use in Australia is the recent review of endosulfan, which led to a number of new restrictions on its use. These restrictions are discussed in Section 2.3.1 and, in summary, require detailed records of use to be maintained, restriction of its use to people who have met specified training requirements, controls on the means of application, and withholding periods for products that have been treated with endosulfan. The NRA would also prevent many of the existing uses of endosulfan beyond 1999–2000 unless industry can convince the NRA that continued use would not pose an unnecessary risk to the environment, consumers and worker safety.

State and Territory management measures

Use of chemicals is also controlled by State and Territory Government legislation, policy and monitoring of standards. Controls over the use of chemicals under Western Australian legislation are implemented through the following legislation:

- *Aerial Spraying Control Act 1996*
- *Agricultural and Veterinary Chemicals (Western Australia) Act 1995*
- *Agriculture Act 1998*
- *Environmental Protection Act 1986*
- *Health Act 1911.*

Controls over the use of chemicals in the Northern Territory are achieved through the:

- *Agricultural and Veterinary Chemicals (Northern Territory) Act 1995*
- *Environmental Offences and Penalties Act 1996*
- *Public Health Act 1997.*

These Acts are implemented through the respective State and Territory Government departments for health, agriculture and environmental protection.

14.2.3 Industry management measures

Industry has recognised that, if strong bureaucratic regulatory involvement is to be avoided, self-management is necessary to minimise the impact of chemicals on the environment. Many industries have demonstrated a strong commitment to self-management and have established best-practice management measures through an ongoing process between industry, researchers, and regulators (Schofield and Simpson 1996).

Examples of the commitment shown by ORIA Stage One farmers to self-regulation include the adoption of an integrated pest management strategy and a spray calendar developed in conjunction with AGWEST (see Section 2.3.1), both of which are designed to minimise the need for chemical applications.

Industry accreditation organisations have also worked with researchers and regulators to develop best-practice management measures. For example, the Aerial Agricultural Association of Australia has a Pilots and Operators Manual that includes detailed information on parameters affecting aerial application of chemicals and the legislative requirements of each State as well as recommendations on application techniques, safety and material handling, and disposal of waste materials (Woods and Lisle 1988).

14.2.4 Management measures proposed for the Project

The use of agricultural chemicals within the Project Area would be minimal in relation to other agricultural industries in Australia. Sugarcane, the dominant crop proposed for the Project Area, has a low requirement for pesticides. Furthermore, the Project Area and its surrounds are characterised by sparse residential settlement. As a consequence of the above factors, the potential for detrimental impact from the usage of agricultural chemicals in the Project Area is considered low.

Any usage of chemicals within the Project Area would be in accordance with Commonwealth and State regulations and industry best practice. Furthermore, any plans for the establishment for residential accommodation within the Project Area, would be controlled through the statutory planning controls in Western Australian and the Northern Territory (Section 11.3.2). Discussions are currently underway with the MfP and the Department of Lands, Planning and Environment to establish the most effective means of controlling residential development within the Project Area. It is anticipated that these controls would be enacted via the Kununurra Town Planning Scheme, and the proposed planning scheme for the Northern Territory, and would take full cognisance of public health issues.

Management measures to minimise potential health impacts outside the Project Area would focus on the minimisation of chemical use and the control of the main transport mechanisms of chemicals, as described below.

Airborne transport of chemicals

In order to minimise the potential for spray drift, the application of any chemicals within the Project Area would be from tractor-drawn boom-sprays whenever possible, utilising technology that results in relatively large spray droplets being released close to the ground. Studies into spray drift due to the use of boom-sprays on the Darling Downs in Queensland, where drift into sensitive crops can be a significant problem, suggest that it should be possible to spray within a metre or two of a susceptible crop (Wylie 1997). At worst, with

the boom-spray set low to the ground and under favourable wind conditions, drift is not likely to travel more than a boom-spray width downwind of the target zone (Wylie 1997).

In other circumstances, for example when ground or crop conditions prevent tractor access, it may be necessary to utilise aerial spraying. In these instances only operators who have successfully undertaken the pilot accreditation programme of the Aerial Agricultural Association of Australia would be utilised, and the timing and manner of application would be carefully chosen to minimise spray drift. Studies of spray drift from aerial spraying have shown that the drift can generally be limited to the target area, but United States Environmental Protection Agency modelling indicates that drift can sometimes extend up to 400 m downwind (Woods and Dorr 1997). Notwithstanding the results of the United States Environmental Protection Agency modelling, registration authorities in Britain require buffer zones of only 6 m for surface rigs and 250 m for aircraft, depending on the nature of the pesticide, the type of crop, and the application method (Woods and Dorr 1997).

Furthermore, a monitoring programme conducted at four sites around Coffs Harbour in New South Wales during the five-month banana-spraying season during 1995 detected only chemicals associated with domestic use and termite control and not those from the adjacent agricultural operations. The study concluded that 'even in a semi-rural town with nearby widespread use of agricultural chemicals, community exposure to pesticides in ambient air may largely relate to their non-agricultural use' (Woods and Dorr 1997).

The Project Area is well separated from existing residences. The only residential settlement currently within the Project Area is the Spirit Hills Station homestead, and this would be resumed as part of the proposed development. Outside the Project Area, the nearest existing settlement, the Maralum Aboriginal community, is over 5 km away (see Section 11.2). Furthermore, the main residential area of Kununurra is situated approximately 36 km to the south-west of the Project Area. Farm residences within ORIA Stage One are located closer to the Project Area but those would be well outside the expected range for spray drift from aerial application. It seems clear that existing residences would not be impacted by airborne chemical spray drift by virtue of their distance from the Project Area. The dominance of south-easterly winds throughout the year (see Section 13.1) would also direct any airborne chemicals away from the major settlement areas of Kununurra and ORIA Stage One, which are located to the south-west of the Project Area.

A test kit has been developed by the University of Queensland that allows a rapid assessment of the placement deposit patterns in the field following spray operations. This information can be used to calculate optimum flight lane separations or, if drift is of concern, to determine the extent of drift associated with the spraying operations (Woods and Dorr 1997). This kit, or an equivalent process, would be used by the proposed Environmental Management Entity (Chapter 16) to monitor spraying operations within the Project Area as part of the EMP to be developed for the Project.

Surface water transport of chemicals

The risk of transporting chemicals from the Project Area in surface water to adjacent areas would be minimised through the on-farm water management systems described in Chapter 5. Furthermore, future use of surface waters downstream of the Project Area for potable water supplies is considered unlikely.

Percolation of chemicals to groundwater

Percolation of chemicals to groundwater is a complex process that is not yet well understood in Australia (Schofield and Simpson 1996). However, experience in the agriculture industry in New South Wales suggests that chemical movement in groundwater within black soils is not significant due to low hydraulic conductivity and the chemical characteristics of the heavy clay soils (Edge 1996). The portion of the Project Area developed for farmland would be exclusively black soil, and as a consequence percolation of significant volumes of agricultural chemicals to the groundwater is considered unlikely.

The low pesticide requirements for sugarcane cultivation combined with the prevalence of heavy soils suggest that contamination of Project Area groundwater by agricultural chemicals is unlikely. Nonetheless, as an additional precaution, groundwater would be tested on a regular basis for all chemicals used in the Project Area to ensure compliance with national drinking water quality guidelines.

15 Community issues

This chapter outlines community and social issues relevant to the proposed development, including predicted changes to the regional economy and population. The chapter investigates the potential for social impacts from the Project, and the planning process that would be adopted by Government to minimise adverse impacts and maximise positive impacts. Issues raised during community consultation activities undertaken for the Project from 1996 to February 1999 are also described.

15.1 EXISTING SOCIAL ENVIRONMENT

15.1.1 The Kimberley region

The Kimberley region represents the northernmost portion of Western Australia, extending between latitudes of approximately 14–20 degrees. It is bounded by the Timor Sea, the Indian Ocean, and the Great Sandy and Tanami deserts.

The nearest population centres to the Project Area are the towns of Kununurra and Wyndham. Both towns are in the Shire of Wyndham – East Kimberley, within the Kimberley region of Western Australia. The nearest population centres in the Northern Territory are the settlement of Timber Creek and the town of Katherine, respectively around 220 km and 510 km east of Kununurra.

In 1996, the Kimberley region had an estimated population of 25,059 (Australian Bureau of Statistics 1996), which is approximately 1.5% of Western Australia's population. Tourists to the region in the dry season can increase the population by over 25%.

As shown in Table 15.1, the population of the Kimberley increased by 11% between the 1991 and 1996 censuses. This growth is slightly higher than the State average of 9%. The rate of unemployment decreased between 1991 and 1996, and has remained below the State average.

Three-quarters of the Kimberley population reside in urban centres. The remaining one-quarter is scattered through about twenty relatively large and sixty smaller Aboriginal communities, 100 pastoral stations, seven mining sites and in the farm area of ORIA Stage 1.

The age and sex profiles of the communities in the Kimberley differ significantly from Western Australia as a whole. The age structure of the male population of the Kimberley compared with the whole of Western Australia is shown in Figure 15.1, while Figure 15.2 provides similar information for the female population. In general, the age and sex profiles of the Kimberley population, in comparison with the rest of Western Australia, is characterised by:

- a substantially higher proportion of people aged below 14 years;

- a substantially higher proportion of young adults aged 25–39 years;
- a slightly lower proportion of people aged 40–49 years;
- a slightly lower proportion of people aged over 49 years.

Table 15.1 Population, employment and household income in the Kimberley region

Indicator	Wyndham urban centre/ locality	Kununurra urban centre/ locality	Kimberley Statistical Division	Western Australia
Population				
Resident population 1991	859	4,062	29,627	1,587,050
Resident population 1996	868	4,884	33,028	1,726,095
Percentage change 1991–96	+1%	+20%	+11%	+9%
Percentage of population in labour force				
Employed 1991	85%	90%	89%	88%
Unemployed 1991	15%	10%	11%	12%
Employed 1996	94%	94%	94%	92%
Unemployed 1996	6%	6%	6%	8%
Weekly household income 1996 (percentage of households)				
\$0–\$500	38%	22%	33%	38%
\$501–\$1,000	35%	34%	35%	33%
\$1,001+	27%	44%	32%	29%

Source: Australian Bureau of Statistics 1996.

About one-quarter of the Aboriginal population of Western Australia lives in the Kimberley region, and Aboriginal people comprise about 34% of the total population of the Shire of Wyndham – East Kimberley (Australian Bureau of Statistics 1996).

The Aboriginal and non-Aboriginal populations display very different demographic and settlement trends (Kimberley Development Commission 1993). Figure 15.3 and Figure 15.4 show that the Aboriginal population is demographically stable, very young (40% under 15 years of age), and has a well-balanced sex ratio. This accounts for the high proportion of people below 14 years in the population as a whole. By comparison the non-Aboriginal population is more transient, is 56% male, and has a disproportionately high representation of persons aged 25–54 years, many of whom are in the community to obtain work. This explains the high representation of people aged 25–39 years in the population as a whole.

15.1.2 Shire of Wyndham – East Kimberley

Kununurra is the nearest town to the Project Area, approximately 30 km from the nearest area proposed for agricultural development. The town is the major urban and commercial centre for the Shire of Wyndham – East Kimberley, and is approximately 3,200 km by road from Perth and 850 km from Darwin. Kununurra was created in the early 1960s to service the development of ORIA Stage 1.

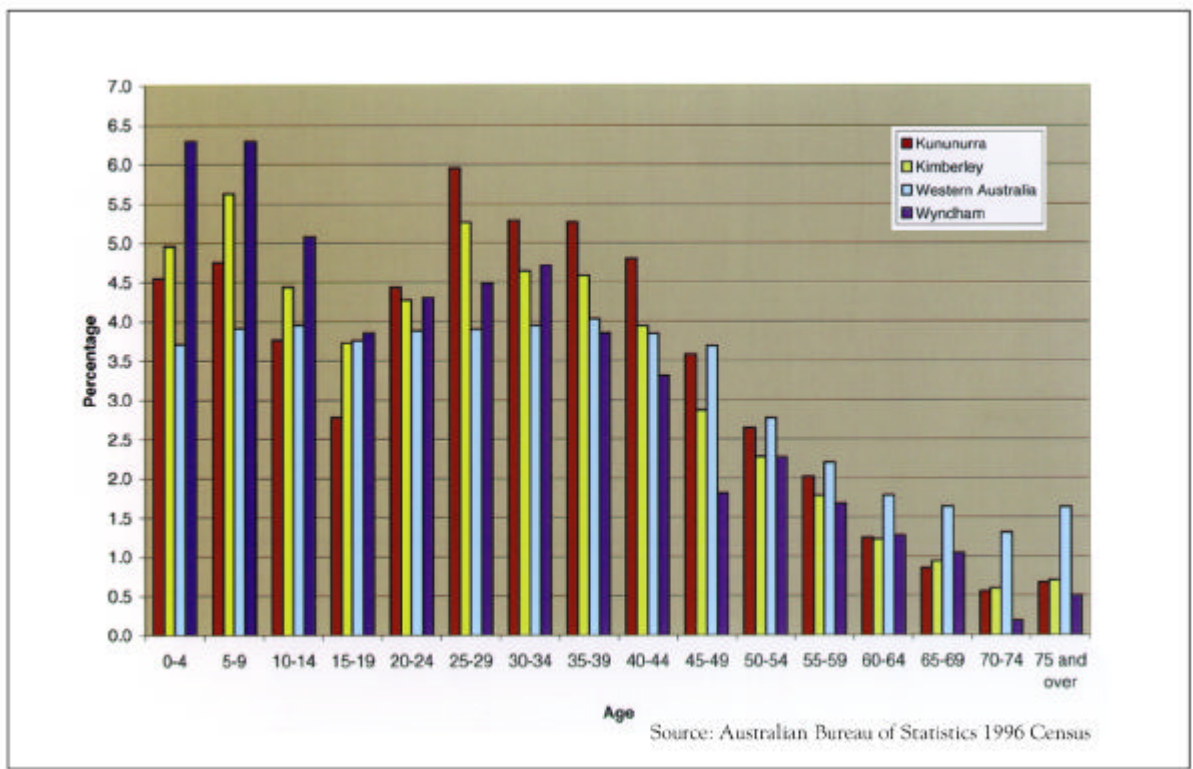


Figure 15.1 Male age structure in the Kimberley region in comparison with the whole of Western Australia

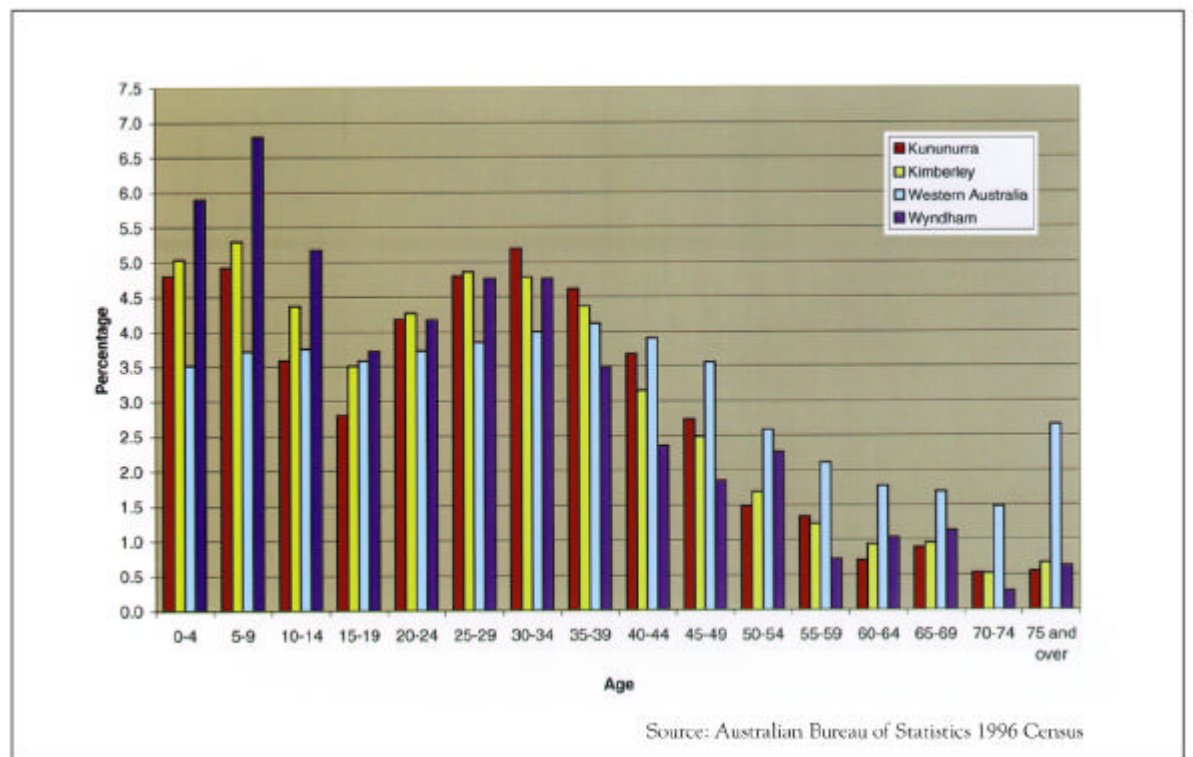


Figure 15.2 Female age structure in the Kimberley region in comparison with the whole of Western Australia

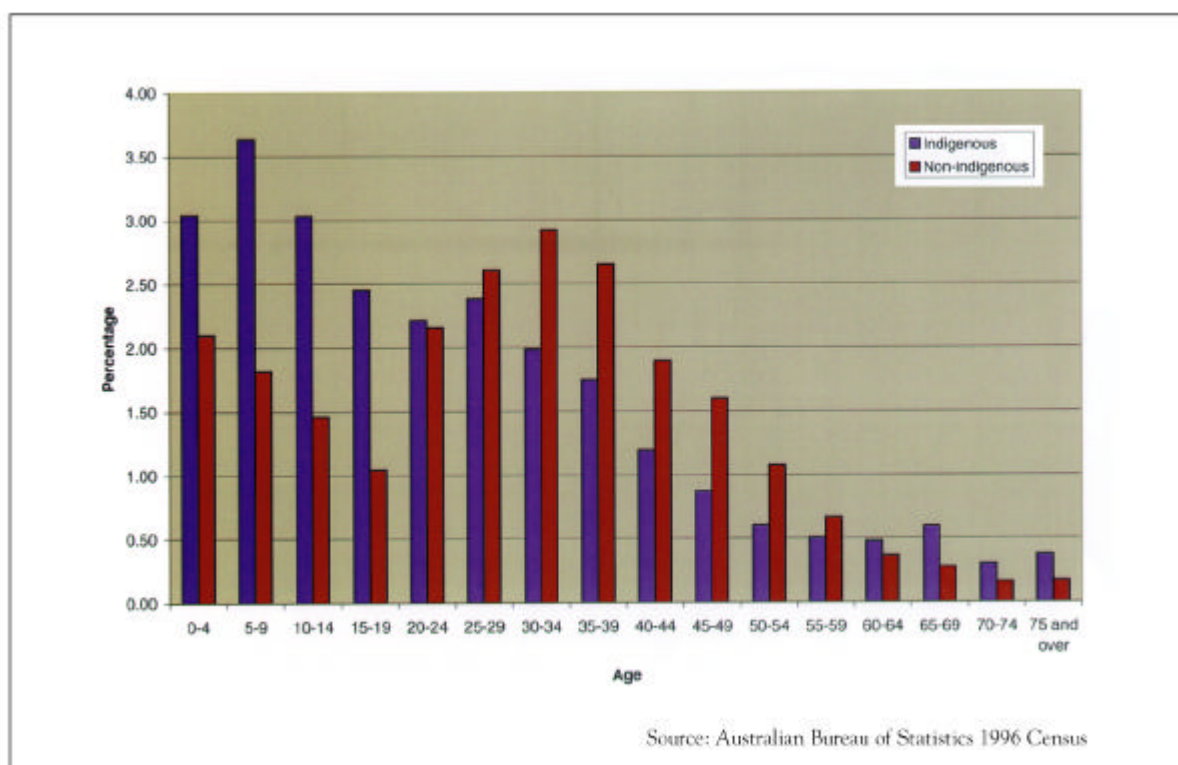


Figure 15.3 Age structure of Kimberley females in the Aboriginal community

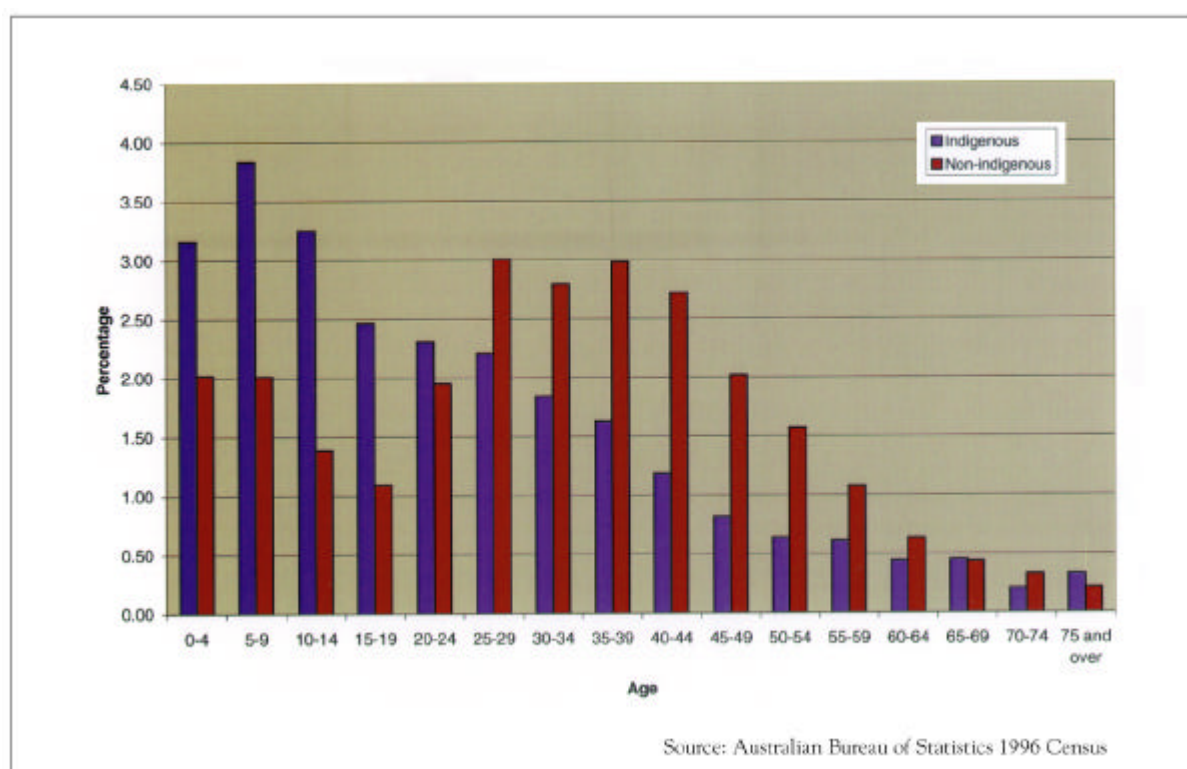


Figure 15.4 Age structure of Kimberley males in the Aboriginal community

Kununurra has experienced steady population growth since its establishment, from 337 people in 1961 to 4,884 in 1996 (Table 15.2). From 1991 to 1996, the population grew from 4,062 to 4,884, an increase of approximately 20%. This population growth is significantly higher than the State average of 9% over the same period and the Kimberley average of 11% (Table 15.1).

Table 15.2 Population trends for Kununurra and Wyndham

Township	1961	1966	1971	1976	1981	1986	1991	1996
Kununurra	337	975	1,240	1,540	2,081	3,137	4,062	4,884
Wyndham	958	1,421	1,515	1,383	1,509	1,329	859	868

Source: Beckwith & Associates 1997.

Located 100 km northwest of Kununurra on the Cambridge Gulf, Wyndham is the second largest population centre in the Shire of Wyndham – East Kimberley. In contrast to Kununurra, Wyndham is over a hundred years old, having been established in the 1880s around the time of the discovery of gold in Halls Creek. Wyndham is the nearest port to Kununurra.

Wyndham experienced a decline in population (Table 15.2) from 1981 to 1991, but the population has stabilised over the past eight years. The decline has been attributed to two factors: the closure of the local abattoir and more recently of the Wyndham prison, and growth in employment opportunities in Kununurra.

The age and sex structure of the people living in Kununurra follows the pattern of the Kimberley as a whole (Figure 15.1 and Figure 15.2). However the young (0–14 years) Aboriginal population is not as pronounced in Kununurra where the Aboriginal proportion of the population is much lower than the rest of the Kimberley region. Also the higher proportion between 25–54 years is more pronounced due to the higher proportion of non-Aboriginal people.

The age and sex structure of the people living in Wyndham also follows the pattern of the Kimberley as a whole (Figure 15.1 and Figure 15.2). However the Aboriginal population aged 0–14 years is greater than the rest of the Kimberley due to the greater proportion (41%) of Aboriginal people in Wyndham. Also, the higher proportion of people aged 25–39 years is less pronounced in Wyndham due to the lower proportions of non-Aboriginal people.

In terms of ethnicity, Kununurra has a similar proportion of people born in mainly English-speaking countries to that of the Kimberley as a whole and Wyndham (97%). This proportion is higher than the figure for the whole of Western Australia (88%).

A comparison of socio-economic indicators (Table 15.1) indicates that, in 1996, the portion of weekly household incomes in excess of \$1,000 in Kununurra was higher than the Kimberley as a whole. Compared with the Western Australian average, Kununurra had lower unemployment and a higher proportion of weekly household income in excess of \$1000. The normal labour force participation rate in Kununurra (63%) is similar to Western Australia as a whole (64%), but lower than Wyndham (69%) and the Kimberley (71%).

According to the 1996 Census (Australian Bureau of Statistics 1996) 25% of all employed persons in the Aboriginal and Torres Strait Islander Commission Wunan Region (Kununurra region) are Aboriginal, compared with an Aboriginal population of 35% of the total population. Unemployment within the Aboriginal population is approximately 8%,

compared with 4% for non-Aboriginal persons. Approximately 54% of the Aboriginal persons employed have found work under the Community Development Employment Projects (CDEP) programme (Australian Bureau of Statistics 1996). The CDEP programme provides employment and community development opportunities where conventional market activity is relatively scarce. Official employment statistics include CDEP participants as employed persons. The statistical effect of this is likely to mask the proportionate underemployment of Aboriginal people as reflected by the published labour force data (Kimberley Development Commission 1999).

15.2 EXISTING REGIONAL ECONOMY

A number of indicators illustrate that the Kununurra–Wyndham area possesses a healthy, growing and diversifying economy (Ministry for Planning 1998). Retail and other commercial activities, largely centred on Kununurra, show sustained year-round spending patterns, and building activity has remained steady throughout the past decade. Pastoral activities have remained buoyant through periods where other industries have struggled. Tourism has shown consistent growth and this is predicted to continue. Population projections prepared by the MfP suggest that the population of Wyndham – East Kimberley may grow to 9,200 by 2011 (Kimberley Development Commission 1996).

The dominant industries in the Kimberley region are mining, tourism, fishing and aquaculture, irrigated agriculture and pastoralism (Table 15.3). Whilst mining dominates in terms of Gross Domestic Value, the fly-in/fly-out component of some of the operations has limited the regional economic flow-on effect (Kimberley Development Commission 1997).

Table 15.3 Kimberley region economic summary

Industry (year)	Gross Domestic Value (\$ millions)
Minerals and petroleum (1997–98)	631.0
Retail trade (1997–98)	240.6
Fishing and aquaculture (pearling) (1997–98)	166.1
Tourism (1996)	107.5
Construction (1997–98)	66.4
Irrigated agriculture (1997–98)	59.0
Pastoralism (1996–97)	42.7
Manufacturing (1996–97)	41.9
Total	1,355.2

Source: Kimberley Development Commission 1999.

Mineral and petroleum production from the region, largely from diamond production at the Argyle Diamond Mine and from zinc/lead mining on the Lennard Shelf near Fitzroy Crossing, represents 3.5% of Western Australia's mining revenue. Other mining activities include iron ore production at Cockatoo Island and onshore crude oil production in the Canning Basin. Exploration activities include the search for offshore and onshore petroleum, diamonds, gold and a range of other minerals.

Tourism has become a major industry in the Kimberley with the region's scenic beauty and unique landforms being important drawcards for tourists. Due to the climate of the region, tourism is largely a seasonal industry, with an estimated 60% of tourists arriving during the dry season (April to September). The Western Australian Travel Survey produced by the Western Australian Tourism Commission estimated that there were 260,000 visitors to the

Kimberley region in 1996. Major tourist attractions and events are presented in Chapter 11. The lack of available tourist accommodation in Kununurra during the peak season has been an issue for a number of years and is viewed by the tourism industry as a limiting factor for future tourism growth. The other main constraint identified by the industry is the limited transportation infrastructure in the area, including the lack of an international airport.

The fishing industry in the Kimberley includes catches of wild stocks and an aquaculture industry sector dominated by pearling. It incorporates the Broome and Kimberley prawn fisheries, the Lake Argyle freshwater catfish fishery, the Kimberley gillnet and barramundi fishery, the Kimberley trap and demersal line fisheries, part of the North Coast shark fishery and an abalone fishery zone. In 1996 there were twenty boats licensed to catch demersal scalefish, ten boats to catch shark and ray, while another fourteen boats were licensed to catch catfish, barramundi and threadfin salmon. Pearling was the most significant activity in terms of financial return and small catches of lobster, crab, abalone and squid also made a contribution. It is noteworthy that the Kimberley's pearling industry has become Western Australia's highest value aquaculture industry. A significant part of the State's prawn fishery is sourced from the Kimberley and over the past decade the local finfish catch has also increased substantially.

The pastoral industry and irrigated agricultural operations are the two major activities contributing to agricultural production in the region. In 1997, the Australian Bureau of Statistics estimated there were 182 agricultural holdings in the Kimberley, covering an area of 24.6 million ha. Irrigated agricultural production has increased significantly in recent years; it is based predominantly on horticultural and broad-acre crops grown in the ORIA near Kununurra and also includes smaller agricultural holdings near Broome and Derby. The pastoral industry is based on rangeland production of beef cattle, which are exported live from the region to a variety of international markets, and also transported to domestic markets.

The commercial sector makes a significant contribution to the region's economy, which has a range of small and large businesses operating in a range of industry sectors. Most activity occurs in the urban centres of Broome, Derby, Fitzroy Crossing, Halls Creek, Kununurra and Wyndham. According to the 1997 Business Register Count, there are 1,498 businesses in the Kimberley. This is an increase of nearly 20% since 1995, when 1,253 businesses were registered. The wholesale and retail trade sectors employed 1,136 people in 1996 and another 585 were employed in finance, insurance, property and business services.

Manufacturing in the Kimberley region makes a small contribution to total economic activity and is primarily small scale. It supports the tourism, agriculture and mining industries, although most of the establishments specialise in food and beverage production. Other activities include production associated with the construction and metal fabrication industries.

The building and construction industry has a significant impact on employment and income in the Kimberley. At the 1996 Census, there were 562 Kimberley residents employed in construction, and the 1997 Business Register Count recorded 143 businesses in this sector. There were 389 residential dwelling approvals in 1997–98, with strong growth occurring in both residential housing and non-residential building projects.

Aboriginal communities and services provided to those communities, attract significant inflows of economic resources in the region. The Kimberley Development Commission (1999) states that research by the Australian National University in 1993 found that

expenditure directed towards Aboriginal people through a wide range of Government and non-Government programmes amounted to a total of more than \$60 million annually. The circulation of income and expenditure through the Kimberley economy arising from these programmes has a substantial positive impact on overall employment and business activity in the region. Impacts are felt particularly in the wholesale and retail trade areas, in building and construction and in some of the service industries. The programmes have also resulted in substantial infrastructure development.

Much of the income and expenditure derived from Government transfer payments is year-round, which contrasts with the seasonal nature of other regional industries, particularly tourism. An important economic stabilising effect results from the steady inflow of regional income provided by social support programmes such as the CDEP, as well as from a range of other programmes that support infrastructure development in communities and from the many organisations that provide services to Aboriginal people.

15.3 WORKFORCE AND POPULATION PROJECTIONS

15.3.1 Characteristics of the existing workforce

The workforce structure by industry in Kununurra, Wyndham and the Shire of Wyndham – East Kimberley is summarised by industry sector in Table 15.4. Of particular interest is employment in the base sector—agriculture, fishing, mining, tourism and welfare—which, in previous studies (Kimberley Development Commission 1996), has been estimated to provide about half (54%) of the employment in the Shire of Wyndham – East Kimberley. Due to the development of ORIA Stage 1, agriculture is a significant employer in Kununurra and is responsible for about 23% of the direct and indirect employment in that urban centre.

Direct employment generated by ORIA Stage 1

In terms of direct employment, it is estimated that ORIA Stage 1 generated employment of 373 full-time equivalent personnel in 1994–95 which represented approximately 12% of the total employment in Kununurra (Kimberley Development Commission 1997). Included in this estimate is casual employment, which peaked at between 200 and 250 jobs between September and November. It is also estimated that casual staff positions may be as high as 1,500 per annum, and that casual staff could be occupying a number of positions throughout the year (Kimberley Development Commission 1996).

Direct employment associated with ORIA Stage 1 includes work in relation to on farm activities (103 full time equivalent) and related activities (270 full time equivalent) such as water supply and maintenance, research and crop reporting, and secondary processing such as sugar milling (Kimberley Development Commission 1996).

Indirect employment by ORIA Stage 1

Indirect employment refers to jobs in businesses supplying goods and services to the agriculture sector. In 1996, the KDC studied the economic impacts of the existing agricultural industry in Kununurra and determined that the indirect employment created by ORIA Stage 1 was approximately sixty-four full-time equivalent positions. The resultant employment multiplier, the ratio of total (direct plus indirect) jobs over direct jobs, is therefore approximately 1.17. This low figure is consistent with the high expenditure outside of the region (84%) by local supply businesses and retailers.

Table 15.4 Employment by occupation in the Shire of Wyndham – East Kimberley

Industry sector	Kununurra		Wyndham		Shire of Wyndham – East Kimberley	
	Number of people	Percentage of total	Number of people	Percentage of total	Number of people	Percentage of total
Agriculture, forestry, fishing	191	10%	11	4%	374	10%
Mining	30	2%	0	0%	394	11%
Manufacturing	115	6%	6	2%	150	4%
Electricity, gas and water	41	2%	0	0%	49	1%
Construction	139	7%	10	4%	230	6%
Wholesale trade	91	5%	12	4%	135	4%
Retail trade	190	10%	28	10%	265	7%
Accommodation, cafes and restaurants	138	7%	6	2%	230	6%
Transport and storage	138	7%	21	8%	207	6%
Communication services	20	1%	3	1%	24	1%
Finance and insurance	42	2%	3	1%	51	2%
Property and business services	155	8%	12	4%	209	6%
Government administration and defence	130	7%	37	13%	188	5%
Education	162	8%	44	16%	264	7%
Health and community services	147	8%	57	21%	438	12%
Cultural and recreational services	19	1%	6	2%	38	1%
Personal and other services	82	4%	6	2%	162	5%
Non-classifiable economic units	34	2%	0	0%	65	2%
Not stated	62	3%	18	6%	159	4%
Total	1,926	100%	280	100%	3,632	100%

Source: Australian Bureau of Statistics 1996 Census

Induced employment by ORIA Stage 1

Induced employment refers to jobs created by the personal consumption and public support of people employed directly and indirectly in the agriculture sector. Quantification of induced effects is technically difficult due to the complexity of later-round expenditure flows, difficulties in obtaining information about personal spending habits, and the lack of a clear and direct link between activity on farm and activity in sectors such as community support (Kimberley Development Commission 1996b).

In 1996, the KDC provided a highly qualified order-of-magnitude estimate that ORIA Stage 1 supported, or justified, around one-fifth of the employment in the non-base (service) sectors. In terms of employment, this equated to about 340 full-time jobs in 1994–95.

15.3.2 Project workforce

Operational workforce

The estimated direct workforce required for the proposed development would be approximately 550 full-time equivalent positions. This estimate includes employment on the corporate and independent farms, in management and administration, in the sugar mill, in harvest and transport operations, and water supply operation. If the estimated employment multipliers that apply to ORIA Stage 1 were used, an estimated indirect workforce of about ninety-five people and an induced workforce of about 500 people would result. However, both of these are likely to be overestimates, particularly the induced workforce, as they would be based on the assumption that all service industries in Kununurra were operating at full capacity. In reality this is unlikely to be the case, and Project planning has therefore been based upon an estimated indirect workforce of seventy-five people and an induced workforce of 200.

Construction workforce

It is expected that, over a three-year period, the numbers of construction personnel would range from 250 to 650 per annum. While as many construction workers as possible would be sourced locally, it is anticipated that the majority would originate from outside the Shire of Wyndham – East Kimberley and would be accommodated in a self-contained construction camp to be built in the centre of the Project Area. The anticipated workforce numbers that would be accommodated at the construction camp are shown in Figure 5.5. It is envisaged that construction workers would work on a six-weeks-on/one-week-off roster, and return to their places of origin during their ‘off’ period.

The construction camp would initially be developed to accommodate approximately 650 construction workers at any one time, all with ‘single’ status. At the completion of construction, part of the construction camp may be removed off site, leaving a reduced number of approximately 200 accommodation units for use by seasonal workers during the operational phase of the Project (Section 15.4.2).

15.3.3 Local population projections

A number of assumptions have been made in order to calculate the likely increase in permanent population resulting from the Project. These assumptions have been based on the premise that the characteristics of the additional operational workforce would be the same as those recorded by the 1996 Australian Bureau of Statistics Census, namely that:

- of the new workforce (direct, indirect and induced) approximately 75% would live with their family in Kununurra and 25% would live as single persons;
- of those who are married, 65% would be in households with children while 35% would be couples without children;
- there would be on average a single full-time worker in every household with children, and 1.3 full-time workers in every household without children;
- the average size of households with children would be 4.

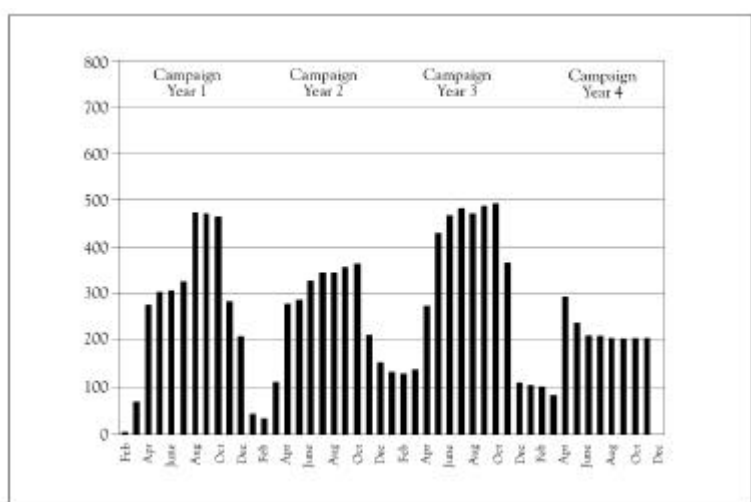


Figure 15.5 Camp workforce numbers

Table 15.5 provides two projections for the increase in population of Kununurra that could result from the Project. These projections relate to two assumptions regarding the number of employment positions that would be filled by people currently living in Kununurra and who are currently not fully employed. Such people include the unemployed (128—1996 Census), and people who are underemployed (people in part-time employment or currently not seeking employment). One scenario is the ‘high projection’ of resultant population increase, which assumes that seventy-five currently unemployed or underemployed people in Kununurra would gain full-time employment as a consequence of the Project. The other scenario is the ‘low projection’ of resultant population increase, which assumes that 300 of the currently unemployed or underemployed population would gain full-time employment as a consequence of the Project.

It can be seen from Table 15.5 that the estimates of net population increase in Kununurra range from 1,367 persons to 1,954 persons.

Table 15.5 Estimated profile of additional workforce and resulting population increase

Profile characteristic	Low projection	High projection
Workforce characteristics		
Direct	550	550
Indirect	75	75
Induced	<u>200</u>	<u>200</u>
Total increase in local workforce	825	825
Labour supplied locally	<u>300</u>	<u>75</u>
Net increase in local workforce	525	750
Household type		
Single (25% of new workforce)	131	188
Couples without children (1.3 workers per household)	106	151
Families (1.0 worker per household)	256	366
Resultant population		
Single (household type × 1)	131	188
Couples (household type × 2)	212	302
Families (household type × 4)	1,024	1,464
Total resultant population	1,367	1,954

15.4 SOCIAL IMPACT ASSESSMENT

15.4.1 The Kununurra–Wyndham Area Development Strategy

The Kununurra–Wyndham Area Development Strategy (KWADS) is in the final stages of preparation by the MfP, in cooperation with the KDC, the Shire of Wyndham – East Kimberley and the Department of Lands, Planning and Environment.

KWADS is intended to provide direction for the long-term use and management of land in the Kununurra–Wyndham area. It will also promote further coordination of activities and initiatives of community, private enterprise and Government agencies with responsibilities in the area. The purpose of the strategy is to:

- formulate a long-term (twenty-five years) development strategy for the Kununurra–Wyndham area, thereby providing a consistent focus for Government agencies;
- prepare a subregional plan that will guide land use, development and conservation;
- prepare structure plans for the towns of Kununurra and Wyndham for future urban expansion and community infrastructure coordination;
- provide guidance for the development of the Lake Argyle Development Node, Mantinea Flats, new service centres for ORIA Stage 2 and for Aboriginal community settlement planning;
- identify areas for further research.

When adopted, the outcomes of the strategy will:

- provide the basis for the review and preparation of the local town planning schemes;
- provide the basis for statutory planning and development control;
- provide a basis for servicing and transport agencies to plan future requirements;
- guide planning, development and conservation in the area;
- define new mechanisms for implementing ongoing cooperation and coordination between the community, industry, the Shire of Wyndham – East Kimberley, and the Western Australian and Northern Territory Government agencies involved in planning and management.

A public consultation programme formed an integral part of KWADS. The consultation programme included the Northern Territory Government, as a portion of ORIA Stage 2 is in the Northern Territory.

Of importance to the Project is that KWADS is to consider the land-use planning and infrastructure needs of the Kununurra–Wyndham area in the context of further development of ORIA Stage 2, including the Project Area. This should provide a sound basis for statutory authorities to plan the long-term provision of services in the area, including a significant expansion of Kununurra.

15.4.2 Housing development

Discussions with the Shire of Wyndham – East Kimberley have indicated that it has a strong preference for the Project workforce to be based in existing urban areas within the Shire

(Andrew Hammond, Shire of Wyndham – East Kimberley, *pers. comm.*), rather than in purpose built accommodation in the Project Area. Kununurra currently has limited stock of surplus housing and if the Project workforce were to be based in existing urban areas, it is clear that additional residential accommodation would have to be developed in Kununurra, and possibly Wyndham.

If it were assumed that purpose built accommodation would be required for all workers associated with the Project; direct, indirect and induced; the accommodation demand would be as summarised in Table 15.6.

Table 15.6 Accommodation requirements for additional workforce

Household type	Low projection	High projection
Single	131	188
Couples without children	106	151
Families	256	366
Total	493	705

As mentioned in Section 15.3.2, approximately 200 single units may remain operational in the refurbished construction camp following the end of project construction activities. These units may be used by seasonal workers on the corporate farm, by transport and harvesting contractors, and seasonal sugar-mill staff. It is envisaged that the major portion of the Project's accommodation requirements would be serviced by the township of Kununurra.

Sufficient residential lots in the undeveloped portion of the existing Lakeside subdivision and the proposed Hidden Valley subdivision are available for the construction of over 600 additional houses and flats, which would be sufficient to meet the accommodation requirements associated with the proposed development. It is not envisaged that Wesfarmers–Marubeni and the Water Corporation would not be directly involved in the development of the new land for housing. It is anticipated that new residential land would be released for development by DOLA in response to the demand for accommodation created by the Project, and private developers would develop that accommodation.

The lack of tourism accommodation is already a problem in Kununurra, particularly in the dry season. The cumulative effect of project seasonal workers who are not housed at the construction camp and the tourist influx is therefore of particular importance. However, it is expected that significant prolonged demand for temporary accommodation during the project construction period could lead to private development of additional hotels or other short-stay facilities, thus providing a long-term benefit to the tourist industry in Kununurra and the East Kimberley. Expansion of the existing caravan parks may also cater for the demand for additional accommodation.

15.4.3 Infrastructure expansion

Water

Potable water for the construction camp, and for the operational requirements of the Project, would be obtained from bores established in the Project Area and would not impact on the current water supply for Kununurra. Water requirements for Kununurra are currently met from existing groundwater reserves in gravel beds recharged by Lake Kununurra. It is

envisaged that sufficient groundwater reserves would be available for the projected population increase in Kununurra as a result of the proposed development.

Sewerage

An enviro-cycle sewage treatment plant would be provided at the construction camp. Enviro-cycle sewerage treatment plants would also service all sewerage treatment requirements during the operational phase of the Project.

Wastewater treatment facilities in Kununurra are currently at approximately 70% capacity. It is envisaged that the available capacity may need to be increased marginally to cater for the projected population increase for Kununurra.

Power

Power for Kununurra and Wyndham is generated by the Ord Hydro hydroelectric facility at Lake Argyle. The same facility also supplies part of the power requirements for the Argyle Diamond Mine. The facility has a 30 MW capacity, of which about 10 MW is currently dedicated to supply electricity to ORIA Stage 1, Kununurra and Wyndham.

Most of the Project's power requirements would be generated at the sugar mill by the burning of the bagasse residue (in a boiler) from the milling of sugar cane. However, if local generating capacity is not used, there may be a modest additional power requirement from the grid for Project operations during the wet season when the mill would not be operational. Also, further year round demand would be generated by growth forecasts for Kununurra as a result of the Project. It is envisaged that the current system would have the capacity to supply this relatively small additional power demand generated by the Project.

Waste management

Domestic solid waste is currently disposed of at the Kununurra and Wyndham landfill sites. The Kununurra facility currently has some ten years of expected life. However, an increase in the population of Kununurra would lead to a proportionate reduction in the lifespan of the Kununurra site and a new site would have to be developed, probably in the next few years. A new solid-waste management facility would then need to be provided by the Shire of Wyndham – East Kimberley in accordance with the requirements of the Western Australian Health Department and the DEP.

Domestic waste from the Project Area would be collected in bins located at the sugar mill, construction camp and maintenance facilities. The bins would be collected regularly for waste disposal at the Kununurra landfill site.

Airport

Kununurra Airport currently services local and interstate flights. Expansion of the airport is not a requirement for the Project, however, increased numbers of flights may be required.

Roads

Main Roads Western Australia has commenced a study into the road network requirements of the east Kimberley, including roads within and around the Project Area and road connections to Kununurra and Wyndham. The study is being undertaken in two parts:

- investigation of the regional road network needs, which has lead to recommendations regarding the preferred road network for the region;
- route selection and planning for each of the roads part of the preferred network.

The first stage of identifying the preferred regional road network has been completed, and has resulted in the following recommendations of relevance to the Project:

- a second crossing of the Ord River should be provided in the vicinity of Buttons Crossing, linking existing roads in ORIA Stage 1 and Parry Creek Road;
- upgrading and sealing of Parry Creek Road, from the new Ord River Crossing to the junction with Great Northern Highway, should be completed.

When implemented, the above recommendations would provide a more direct route between the proposed sugar mill and Wyndham than is currently available. As well as reducing the travel time for trucks transporting product from the Project, the recommended road network would reduce traffic and noise impacts from these vehicles on the outskirts of Kununurra.

15.4.4 Public services

Medical

The central hospital facility in the East Kimberley is the Kununurra Hospital, which has twenty-six beds with existing demand running at twenty-one or twenty-two beds. There are four doctors on staff and, while some specialist health services are available in Kununurra (i.e. pathology, X-ray, occupational therapy, a private dental clinic), there is no surgeon at the hospital or resident in the East Kimberley. A surgeon visits from the West Kimberley every two to four weeks. There are a part-time general practitioner and two mental health nurses in town, and a psychiatrist visits as required.

The influence of the Project and other ORIA Stage 2 developments has already been factored into the planning requirements of the Kununurra hospital. Plans exist to add another ten beds to the hospital to accommodate any increase in demand for hospital services from anticipated growth. One benefit of an increase in population is that it may lead to a full-time private general practitioner establishing in Kununurra.

It is likely that the East Kimberley Aboriginal Medical Service (EKAMS) would be required to service a larger patient load due to a significant increase in the non-Aboriginal population in Kununurra. Currently, more than 30% of the patients using the EKAMS are non-Aboriginal. Increased resource allocations for the EKAMS or changed policies on access to the clinic in Kununurra may be required to avoid delays in the provision of medical services to Aboriginal patients.

Education

Kununurra has two schools: Kununurra District High School (pre-primary to Year 12) and St Joseph's Catholic School, which mainly caters for Aboriginal students of pre-primary and primary age. Currently there is no senior high school in either Kununurra or Wyndham.

The anticipated population growth and projected increase in enrolments may necessitate development of another combined pre-school and primary school, possibly in the vicinity of the Lakeside subdivision. The population growth may also precipitate an upgrade of the

Kununurra District High School to a senior high school, a move that would be welcomed by the local community.

Post-secondary education is offered through the Kimberley College of Technical and Further Education through its centres in Broome, Derby, Halls Creek, Kununurra and Wyndham. The college is expanding its services to the Kimberley region and is currently constructing a new main campus and aquaculture annexe in Broome. Upgraded facilities have recently been completed in Kununurra, Wyndham and Halls Creek.

Other post-secondary facilities in the Kimberley region include telecentres located in Broome, Derby, Halls Creek, Wyndham and Kununurra, which offer education through video-conference and other electronic facilities. These centres are available to regional students enrolled in institutions across Australia.

15.4.5 Regional recreational resources

The Ord River and the Keep River environments play a vital role in the lives of both Aboriginal and non-Aboriginal people in terms of recreation and lifestyle. The Lower Ord River supports significant fishing activity, and angler's fish from the banks and from small boats. Lake Kununurra supports a range of recreational activities, including boating, water-skiing, jet skiing and houseboating. The Keep River is also a popular destination for anglers, although access is currently limited at times due to weather and pastoral activities.

A recent survey (West et al. 1996) highlighted the importance of recreational fishing to the community. The study estimated that 50% of the non-Aboriginal resident population actively participate in recreational fishing, with 40% of survey respondents indicating that fishing was their main or second-to-main outdoor recreational activity. Of the resident Aboriginal population, the study reported that around half had actively participated in fishing in the previous twelve months. West et al. (1996) also reported that fishing for food is more important than sport fishing within the Aboriginal population.

Tourists make up a substantial component of recreational anglers using the Ord River during the dry season. There are at least three commercial charter boat operations that cater for tourists in the dry season.

Given the importance of the local waterways for both recreational and lifestyle purposes, the maintenance of access to the waterways is an important social impact issue. This is particularly true for the local Aboriginal community for whom access to the riverbanks and the water is of socio-cultural importance. The Project has been designed in such a way that access to the Keep River would be maintained (Section 11.4 refers). The proposed development would have no impact on access to the Ord River.

The Kununurra Leisure Centre, which includes a swimming pool, squash courts and gym, is currently operating well below capacity and would readily cope with additional patronage.

Sporting ovals in Kununurra are currently fully utilised. The Shire of Wyndham – East Kimberley is investigating this issue, and it is likely that another oval suitable for training will be developed in the near future to cater for existing needs (T. Brown, Shire of Wyndham – East Kimberley, *pers. com.*, 16 August 1999). A further sporting oval, probably located at Lakeside, may be required if the Project proceeds.

15.4.6 Towns in the Northern Territory

Timber Creek

Timber Creek, some 226 km from Kununurra, is the closest Northern Territory population centre to the Project Area. It is unlikely, however, that the Project would have a significant impact on this community. Any impacts would likely be beneficial, and linked to increased trade for roadhouses, and possible increases in local tourism.

Katherine

The Project is not expected to have any social impact on Katherine, located approximately 500 km northeast of Kununurra. However, local Government officials view Katherine and Kununurra as two communities that complement one another because of their northern locations and investment in horticulture. Horticulture is continuing to expand in Katherine, and some Katherine businesses already carry out work in Kununurra. Expansion of agricultural activities as a result of development of the Project Area may provide the opportunity for expansion of Katherine-based businesses.

15.4.7 Construction workforce issues

The majority of the construction workforce would be accommodated in a construction camp at the centre of the Project Area. This facility would provide accommodation for about 650 workers, which would be sufficient to cater for the peak construction workforce requirements of the Project. Therefore, the social impact of this workforce on the town of Kununurra is expected to be minimal. A high standard of amenities would be provided at the construction camp, including recreation and entertainment facilities, thereby limiting the need for construction workers to travel to Kununurra. It is likely that some would still wish to frequent the townships of Kununurra and Wyndham, which would create additional custom for local businesses.

15.5 COMMUNITY CONSULTATION

Significant community consultation has been undertaken in relation to the proposed development. The consultation has been implemented in two main stages:

- in 1996 and 1997, during preparation of an unpublished Public Environmental Review undertaken by Sinclair Knight Mertz on behalf of the DRD;
- in 1998 and 1999, during preparation of this ERMP/DRAFT EIS.

Objectives of the community consultation programmes, activities conducted, organisations consulted and issues raised are presented in the following sections.

15.5.1 Consultation objectives

The community consultation programme was aimed at:

- ensuring that all interested people, groups and organisations were informed of the Project;
- ensuring that all interested people, groups and organisations had the opportunity to comment on the potential environmental (natural and social) impacts of the Project;

- enabling study teams to understand community values relating to natural resources in the region, as those values related to the proposed development.

15.5.2 Consultation activities

Consultation activities undertaken for the Project are discussed below. A list of organisations that have been consulted is presented in Appendix E.

Media campaign and advertising (ongoing)

The media campaign and advertising have included press releases and interviews with media outlets. Media outlets targeted for the release of information are provided in Table 15.7.

Table 15.7 Media outlets utilised in the community consultation programme

Region	Kimberley Echo	Northern Star Magazine	ABC Radio	Waringarri Radio	Katherine Times	Imparja TV	Hot 100 Radio	NT News	The West Australian	GWN
Kununurra	✓	✓	✓	✓	–	–	–	–	–	–
Broome	–	–	✓	–	–	–	–	–	–	–
Katherine	–	–	–	–	✓	–	–	–	–	–
Northern Territory	–	–	✓	–	–	✓	✓	✓	–	–
Western Australia	–	–	–	–	–	–	–	–	✓	✓

– Indicates media outlets were not used in the region.

Distribution of consultation brochure and response sheets (1996–97)

A mail-out of a brochure describing the Project was conducted in 1996–97 for Kununurra and Wyndham in order to achieve the maximum public awareness of the Project. The brochures included comment sheets that promoted community feedback. The brochures were distributed to all post boxes in Kununurra and Wyndham, were made available at public displays and meetings, and remained available at local council offices for approximately three weeks. A total of 2,500 brochures were printed and distributed.

Direct consultation (1996–97)

Direct contact was made with groups and organisations that were identified as having a specific interest in the Project. This contact was by telephone, fax or letter, and a copy of the consultation brochure was sent or included where appropriate. These groups and organisations were invited to attend a public meeting or to contact the study team to discuss relevant issues. A list of groups and organisations consulted is contained in Appendix E.

Free Call information telephone line (1996–97)

A Free Call telephone line was established and was identified in consultation materials. This line enabled people to ring for more information or to discuss issues they felt were important.

Public displays and meetings (1996)

Public displays and meetings were held at Kununurra, Wyndham, Timber Creek and Katherine over the period 9 November to 14 November 1996. During this period more than 150 verbal inquiries were received and sixty-seven people attended the various public meetings.

Community Relations Team

A Community Relations Team comprising a full-time Community Relations Officer (Wesfarmers) and a full-time Project Manager (the Water Corporation) was established in Kununurra in mid-1998. The role of the team has been to keep the local community informed on issues arising from the development of the Project on a day-to-day basis. This team is supported by regular visits by other staff of Wesfarmers–Marubeni and the Water Corporation and their consultants.

Public displays and meetings (1998–99)

Four public meetings were conducted in Kununurra and Wyndham in 1998. The meetings were informed of progress of key elements of the feasibility study, including the environmental analysis, and provided an opportunity for community feedback. Around 102 people attended the August meeting in Kununurra, and eighty attended the December meeting. Approximately fifteen people attended workshops conducted in Wyndham in the same months. Further meetings are planned.

Environmental workshop (1998–99)

An environmental workshop was conducted in Kununurra on 9 and 10 December 1998. The workshop was attended by some sixty delegates representing the Governments of Western Australia, the Northern Territory and the Commonwealth; conservation and grower groups; Wesfarmers–Marubeni and the Water Corporation and their consultants; and other interested individuals. Issues raised at the workshop were published in conference proceedings, which were issued to all delegates in December 1998.

Individual consultation (1998–99)

Consultation has been carried out with various community groups throughout the course of preparing this ERMP/draft EIS. The organisations consulted are identified in Appendix E.

Consultation with Aboriginal people (1998–99)

Consultation with local Aboriginal people has been extensive during 1998–99 and is ongoing. The Project Community Relations Officer has facilitated this consultation with presentations given to regular meetings with Aboriginal people by staff and consultants of Wesfarmers–Marubeni and the Water Corporation. This consultation is ongoing, and is described further in Chapter 12.

15.5.3 Proposed management measures for key issues

Within the local community there is an almost universal positive attitude towards the Project. Even so, as a major project it carries with it social implications of considerable significance to the existing population and communities within the region. Table 15.8 summarises the major issues raised during the various community consultation programmes, and specifies

the chapter/section of the ERMP/draft EIS that provides information on how the issue would be addressed.

Table 15.8 Summary of key issues raised during community consultation

Issue	Summary of comments	Proposed management measures
State/Territory cooperation, cross-border issues, and compliance with environmental conditions	Consensus needed on issues such as quarantine, power, etc. How will environmental conditions be enforced? Who will conduct the monitoring?	State/Territory cooperation is currently being guided by a Memorandum of Understanding between the two Governments. A Ministerial Council will be established in due course to investigate the cross-border issues and to make recommendations on the development of a consistent set of legislation applicable to the Project Area. An environmental management framework has been developed for the Project, which addresses responsibilities for compliance with environmental conditions and monitoring. This framework is described in Chapter 16 and Appendix O.
Groundwater protection	Rate of accessions to groundwater. Potential for future salinity problems and waterlogging. Sustainability of production.	A proactive groundwater management system has been incorporated into the Project; it includes: • avoidance of areas prone to groundwater problems; • minimisation of groundwater accessions by design standards for infrastructure and water application strategies for farming; • development of a groundwater management strategy, including the use of dewatering bores. The Project has been designed with the intention of achieving sustainable long-term production. Groundwater issues are discussed in greater detail in Chapter 6.
Surface water protection	Impacts upon other users (Lower Ord River). Changes in Ord River and Keep River hydrology, quality and ecology. Impacts (fertilisers and chemicals) of farm discharges.	The hydrology of the Ord River has been changed forever by construction of the dams forming Lake Argyle and Lake Kununurra. The Water and Rivers Commission has commenced the development of a Water Allocation Plan for the river catchment that would balance water allocations to various users, and would include maintenance of environmental values. The Project's water requirements are consistent with the interim allocation proposed by the Commission. A fundamental environmental management feature incorporated into the Project is the provision of tailwater return systems to all farming areas developed. These systems would virtually eliminate regular tailwater discharges and, therefore, many of the water quality issues normally associated with older irrigation schemes would be avoided. Water management issues are described in Chapter 5.
Protection of aquatic ecosystems	Maintenance of riparian vegetation. Control of erosion.	Riparian vegetation within the Project Area along significant watercourses would be conserved. The location and height of flood protection levees have been selected to minimise the effects of erosion.
Protection of terrestrial flora and fauna	Protection of habitat (reserves and corridors). Management of weeds and pests.	The Project strategy includes the provision of conservation areas, including wildlife corridors where appropriate, assessed as providing viable representative samples of the local habitats. A full description of the conservation strategies is presented in Chapter 10. The management measures proposed to mitigate the secondary land-use effects of an increased population and improved access are described in Chapter 11. Management responsibilities for the conservation areas are discussed in Chapter 16.

Table 15.8 Summary of key issues raised during community consultation (continued)

Issue	Summary of comments	Proposed management measures
Maintenance of air quality	Fallout from cane fires. Effects of farm chemicals (herbicides and pesticides) on the environment.	The effect of cane fire fallout on existing residential areas would be naturally ameliorated by the remoteness of the Project Area and specific management measures are not considered necessary. Sugarcane has a low requirement for farm chemicals and it would be the predominant crop for the Project Area. Farm chemical use would be controlled by a combination of statutory and project-specific measures, as described in Chapters 3, 5 and 14.
Aboriginal heritage	Protection of sites. Reduction of areas or quality of areas available for traditional uses. Native Title.	This consultation process has been extensive and is ongoing, with the objective of developing an Indigenous Land Use Agreement that is equitable to all parties. Chapter 12 outlines the consultation process undertaken by Wesfarmers–Marubeni and the Water Corporation with the Miriuwung and Gajerrong people.
Social environment	Development pressures on Kununurra. Potential new township. Adequacy of community facilities. Impacts of tourism and recreational values of the region. Development of community reliance on monoculture creating potential risks.	Most Project accommodation requirements would be sourced from Kununurra, which is perceived to be of economical benefit to the town. The project workforce would be obliged to comply with ongoing community programmes to protect the region's tourism and recreational values. Sugarcane would be the dominant crop; however cropping diversity may be introduced by land developed by independent farmers.

16 Environmental management framework

This chapter outlines the consideration of an environmental management framework for the proposed development which would ensure that the environmental values within the Project Area are protected and maintained in the long term.

The environmental management requirements would largely be defined by the environmental conditions applicable to the proposed development, the commitments made by Wesfarmers–Marubeni and the Water Corporation in this ERMP/draft EIS (see Chapter 17), and relevant statutory obligations.

16.1 THE NEED FOR AN ENVIRONMENTAL MANAGEMENT FRAMEWORK

The proposed development has a number of distinctive characteristics relevant to ongoing environmental management. These include:

- a Project Area that is relatively large and would include related but discrete activities such as the supply of irrigation water, farming and processing;
- a farmed area which would be predominately developed and operated by Wesfarmers–Marubeni in the initial phase but maybe sold down in part or whole to independent farmers in the future;
- a Project Area that straddles the border between Western Australia and the Northern Territory, which may induce cross border issues with respect to environmental compliance legislation;
- the legal recognition of Miriuwung and Gajerrong native title rights over a portion of the Project Area and the existence of native title claims over the balance of the Project Area;
- high community expectations with regard to environmental management.

To address the above-mentioned characteristics Wesfarmers–Marubeni and the Water Corporation consider it appropriate that an environmental management framework is developed for utilisation throughout the development and operational phases of the proposed development. Key elements of such a framework should:

- be structured to suit the proposed development and be site specific;
- clearly and transparently articulate environmental responsibilities and accountability;
- accommodate the need for ongoing environmental monitoring and reporting;
- be appropriately resourced over the long term.

A brief summary of each of the four key elements of the proposed framework is as follows:

A project-specific framework

The proposed development has a number of distinctive characteristics, as noted above. Any environmental management framework would ideally be able to integrate and co-ordinate the management of any potential environmental impact from any individual activity, from an industry-wide perspective, and from a cumulative perspective.

Clear allocation of responsibility and accountability

For effective ongoing environmental management, there would ideally be clear articulation of the responsibility and accountability of all industry participants. This would be important due to the interconnection, from an environmental outcome perspective, between some of the key industry activities.

Ongoing monitoring and reporting

Ongoing management of environmental issues within and around the Project Area would ideally be based on a preventative philosophy rather than the management of any environmental impact after it has occurred. To facilitate a preventative management programme, ongoing monitoring would be required on a range of issues for the thorough and continuous assessment of key environmental performance indicators. Subsequent analysis of the collected information, and the reporting of the results of the analysis against original targets, would ideally be implemented. The results would ideally be made available to appropriate parties to ensure environmental expectations are being met.

Appropriate level of resources

To effectively co-ordinate the environmental management framework, including the ongoing monitoring and reporting, adequate resources should be made available. Funding would ideally be made available for the engagement of personnel and/or consultants for ongoing environmental monitoring and analysis, and the production of reports from environmental analyses.

16.2 RELEVANT LEGISLATIVE ISSUES

As the Project Area straddles the border between Western Australia and the Northern Territory, the proposed development would be subject to a range of State and Territory legislation. Similarities and differences currently exist with respect to relevant State and Territory legislation applicable to the proposed development. For example, the portion of the proposed development within Western Australia would currently be subject to the *Environmental Protection Act 1986*, and the portion within the Territory would be subject to the *Environmental Assessment Act 1994*. Whilst the effect of each Act is substantially similar, differences exist which could give rise to complications during the development and operational phase of the Project.

To address any potential complications which may arise from legislative issues, the State and Territory governments have undertaken to form a Ministerial Council. The Ministerial Council is to comprise Ministers from the State and Territory Governments, and would oversee the recommendation and adoption of appropriate legislation to be applicable over the Project Area.

With respect to environmental issues, it is understood that the *Environmental Protection Act 1986* may apply over the entire Project Area. If that is to be the case, any conditions set by the Western Australian Minister for the Environment in relation to the proposed development would be applicable in Western Australia and the portion of the Project Area in the Northern Territory. Any such conditions would generally be applicable to the prospective asset owners in the initial phase, in this case being Wesfarmers–Marubeni and the Water Corporation.

16.3 ENVIRONMENTAL MANAGEMENT FRAMEWORKS FOR IRRIGATION PROJECTS IN AUSTRALIA

To assist in the conceptual development of an environmental management framework for the Project Area, analysis was completed of environmental frameworks currently being implemented in a number of irrigation areas in Australia. A summary of the research follows.

16.3.1 Ord River Irrigation Area Stage 1

ORIA Stage 1 was developed before environmental legislation existed in Western Australia. As a consequence, ORIA Stage 1 is currently not covered by a single comprehensive environmental management framework (section 2.3.5 refers). Environmental management has historically relied on the compliance of all relevant individuals, groups and agencies with laws and statutes that apply to the prevention of pollution and degradation of land.

Two significant initiatives with respect to a management framework are being undertaken by local industry participants; the preparation of a comprehensive Land and Water Management Plan, and the preparation of a new asset management structure in relation to irrigation and drainage services (Section 2.3.5 refers).

16.3.2 South West Irrigation

South West Irrigation comprises some 12,000 ha of irrigated farmland, in the districts of Waroona, Harvey and Dardanup in Western Australia. Irrigation water is sourced from seven local dams, and over 95% of the irrigation water is used on flood irrigated pastures. The balance of irrigation water is used for horticultural purposes.

The irrigation scheme has been owned and administered by the private sector since 1996. Scheme assets are held by the South West Irrigation Asset Co-operative (SWIAC), and the scheme is operated by the South West Irrigation Management Co-operative (SWIMCO). Both SWIAC and SWIMCO are wholly-owned by some 600 farmers.

Irrigation in the southwest of Western Australia commenced at the turn of the century, and the current scheme was substantially completed by 1966.

South West Irrigation has four key objectives with respect to the management of environmental issues:

- determination of the relevant environmental guidelines for the operation of the South West Irrigation districts;
- assessment of the implications of the environmental guidelines on South West Irrigation;

- promotion of best practice on-farm irrigation management;
- promotion and adoption of environmentally responsible farming.

In 1998, South West Irrigation appointed a Land and Water Management specialist to assist in the delivery of the abovementioned objectives.

16.3.3 Burdekin River Irrigation Area

The Burdekin River Irrigation Area in Queensland, covers 40,000 hectares and, is managed by the Department of Natural Resources of Queensland (QDNR).

Regulation is based on ‘Environmentally Relevant Activities’ under the Queensland *Environmental Protection Act 1994*.

The environmental management of the irrigation area presently revolves around meeting the requirements of the International Standards Organisation’s relevant Standards. These requirements, however, relate only to the activities of staff, and the management and operation of the relevant department within QDNR. QDNR has no jurisdiction over its customers. Lease conditions can contain guidelines on environmental criteria, such as tree clearing, but the regulation and enforcement of these types of criteria are not presently in the scope of operations of QDNR. However, new customers requiring significant allocations of water must submit a Land and Water Management Plan along with any development proposal.

16.3.4 Murray Irrigation Limited

Murray Irrigation Limited is a private company which provides irrigation water and drainage services to 796,000 ha of farmland, and to the towns of Berrigan, Finley and Wakopool in New South Wales.

Each irrigator/landowner is a shareholder in Murray Irrigation Limited, and shares are held in proportion to the water entitlements held by each member. Murray Irrigation Limited has ten company Directors, including eight elected irrigation Directors and two Directors with specialist skills in engineering and finance.

Murray Irrigation Limited has an Irrigation Corporation Water Management Works Licence, a Pollution Control Licence, and water sharing Agreements. The irrigation licence defines the terms, limitations and conditions for the supply of irrigation water to its business. Compliance with this licence is dependent upon responsible use of irrigation water by landholders. The licence, which is issued by the NSW Environment Protection Authority, requires frequent monitoring of drainage water leaving the region for salinity, nutrients, pesticides and turbidity. The Pollution Control Licence includes a requirement for continuous improvement of farm water management and to protect the river environment and downstream water-users from poor quality water leaving their area.

Preparation of Land and Water Management Plans (LWMP) by water users, which are a mixture of environmental and farm management tools and are fundamental to compliance with the licences held by Murray Irrigation Limited. A number of LWMP’s have also been developed by local communities—including Berriquin, Cadell, Denimein and Walcool—with support from the State Government. Murray Irrigation Limited is the implementation authority for these plans.

LWMP's are funded on a 'beneficiary pays' basis. The definition of beneficiary is wide and includes farmers and farming communities and downstream river users. Farming communities contribute more than 70% of the cost of LWMP's via levies. In 1997–98, 23% of Murray Irrigation Limited's operating revenue was derived from LWMP contributions. Another significant source of funding is from State Government grants.

16.3.5 Goulburn Murray Water

Goulburn Murray Water is a State government body, responsible for the provisions of rural water and drainage services to some 68,000 km² in Victoria.

In the district managed by Goulburn Murray Water, individual developers are required to undertake detailed investigation and design work, and to develop a Whole Farm Management Plan (WFMP). A WFMP is intended to provide the basis for high-level irrigation efficiency, leading to maximum productivity for the farmer and minimisation of off-site impacts. Relevant Government agencies—such as the Department of Natural Resources and Environment, local Government, the NSW Environment Protection Authority, Aboriginal Affairs Victoria and catchment management authorities—assess and comment on WFMP's prepared by farmers. These comments usually constitute acceptance or rejection of a WFMP, or require that further investigations be undertaken by proponents. Rejection of a WFMP must be based on legislative authority, approved Government policy or Government-approved independent standards.

Goulburn Murray Water would not approve the transfer of water entitlements to a new development until requirements of all other Government agencies have been met. When all requirements are met, Goulburn Murray Water would issue appropriate written approval for the proposal, and arrangements would then be made to issue a water entitlement for the proposed development.

16.3.6 Coleambally Irrigation Corporation

The Coleambally Irrigation Corporation (CIC) is State government entity, responsible for the provision of irrigation services to some 80,000 ha in New South Wales.

CIC is a Government entity with an independent Board, a Chief Executive Officer, and Administration, Operations and Environment divisions. CIC operates under an Irrigation Corporation Water Management Works Licence issued under the *Irrigation Corporation Act 1994*, and a Pollution Control Licence issued under the *Pollution Control Act 1970*. These licences set a range of conditions on the provision of water and irrigation services. Both of these licences require the preparation and implementation of a Land and Water Management Plan (LWMP), by CIC.

A LWMP has been prepared by the Coleambally community, and submitted to the Government for approval. It has been proposed that CIC be responsible for implementing the plan as the Corporation holds the Bulk Water Supply Licence, Operating Licence and Pollution Control Licence on behalf of landholder members. Water supply contracts between CIC and individual landholders would include conditions reflecting the terms of licences held by CIC. Individual LWMP's are prepared by landholders, and implementation is a contractual obligation on the landholder. Any disputes regarding compliance with LWMP would be dealt with by an Anomalies Committee, comprising landholder members and technical advisers.

A Community Environmental Committee, composed of local community members and a representative of the irrigation community, facilitates community involvement in decision-making.

Negotiations on funding for the implementation of a consolidated LWMP have been in progress since May 1997. The total cost of implementing the plan would be approximately \$140 million. Agreement in principle has been reached on funding arrangements for implementing on-farm management options. Agreement has also been reached for the funding of an education programme.

16.3.7 The Murray–Darling Basin Commission

The Murray–Darling Basin Commission (MDBC) oversees the environmental management of over one million square kilometers of agricultural land in Queensland, New South Wales, Victoria, South Australia and the Australian Capital Territory. Irrigated agriculture in the Murray Darling Basin accounts for around 75% of Australia’s estimated use of irrigated water and for around 70% of Australia’s irrigated area (Crabb, 1997).

The MDBC is a government entity, which is responsible to the Murray–Darling Ministerial Council, which in turn is made up of ministers of the beforementioned State/Territory governments and the Commonwealth.

The MDBC is an autonomous organisation equally responsible to the Governments represented on the Ministerial Council and to the Council itself. The MDBC is not a Government department or a statutory body of any individual Government.

The MDBC consists of an independent President and two Commissioners from each of the contracting Commonwealth and State Governments, these normally being chief executives or senior officials of the agencies responsible for water, land and environmental resources. An ACT Government representative may participate in the deliberations of the MDBC, but not in decision-making. The prime functions of the MDBC are to:

- advise the Ministerial Council on the planning, development and management of the water, land and other environmental resources of the Murray–Darling Basin;
- assist the Ministerial Council in developing measures for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray–Darling Basin;
- equitably and efficiently manage and distribute the water resources of the River Murray in accordance with the Murray–Darling Basin Agreement in order to obtain the highest quality and efficiency of use of such resources.

The MDBC has the mandate to initiate, support and evaluate integrated natural resources management across the Murray–Darling Basin. The Office of MDBC, which is located in Canberra, and MDBC staff are divided into the following two groups:

- The River Murray Water Branch, operating as River Murray Water, which is responsible for the management and distribution of the waters of the River Murray.
- The Natural Resources Management Branch which administers the provisions of the Murray–Darling Basin Agreement, and is responsible for managing the natural resources of the Murray–Darling Basin through the Natural Resources Management Strategy and the Basin Sustainability Program.

The work of the MDBC requires close and constant co-operation with the relevant departments and agencies of all the signatory Governments. Priority is given to those issues that require action by two or more Governments involved in the management of the Murray–Darling Basin.

The MDBC draws upon a network of more than twenty working groups and committees, composed of experts in the various aspects of natural resources management, and other areas for which the MDBC is responsible. The experts are drawn from Government departments and agencies, universities, private companies and community organisations. In this way, the MDBC brings together the best expertise available for the integrated planning and management of the Murray–Darling Basin.

A diagrammatic representation of the Murray-Darling Basin environmental management framework is as follows:

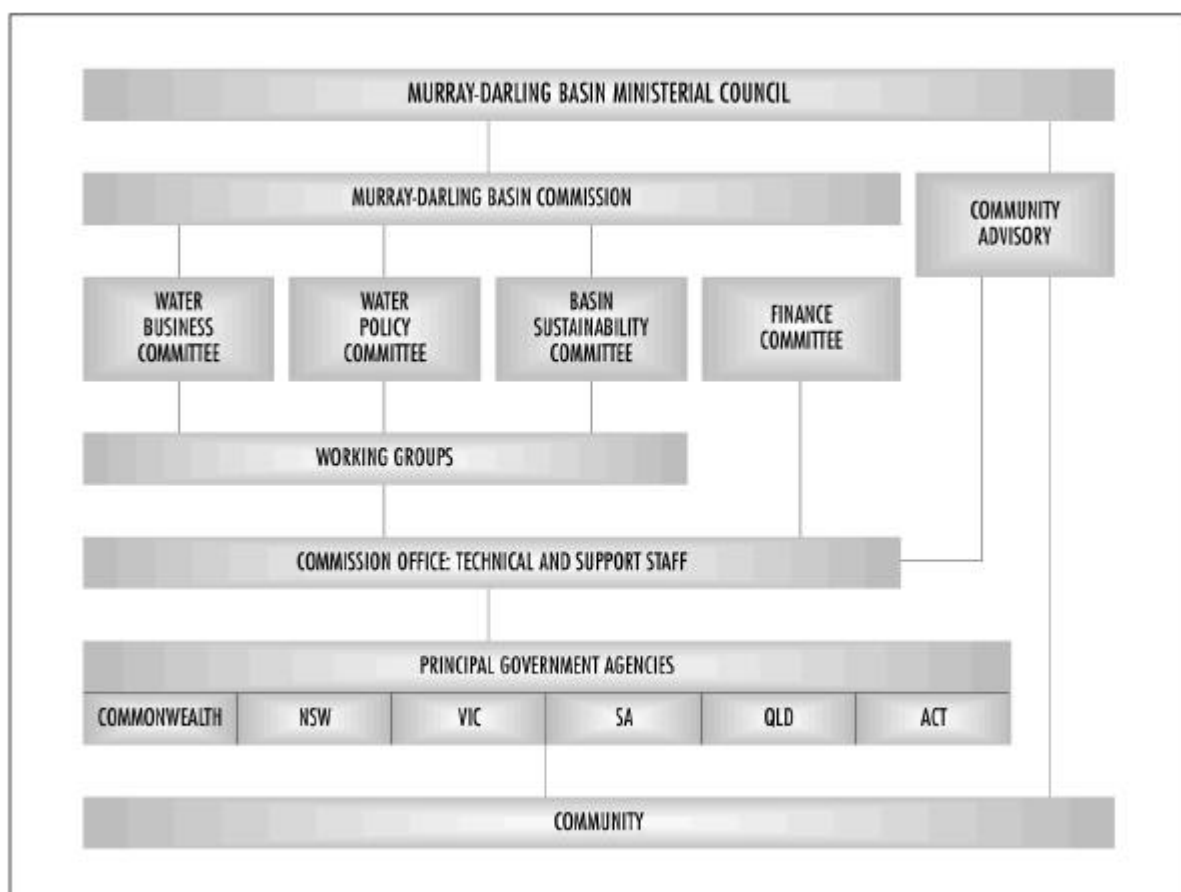


Figure 16.1 Murray-Darling basin environmental management framework

16.4 THE PROPOSED ENVIRONMENTAL MANAGEMENT FRAMEWORK FOR THE PROJECT

16.4.1 The Case for Self-Management

Most of the environmental management frameworks currently operational in Australia have been developed to ‘retrofit’ existing operations. Furthermore, the industry being retrofitted is often characterised by a relatively large number of participants, ranging from small-scale operators to government agencies. As a consequence, and to balance existing and often competing interests, the environmental frameworks can be relatively complex and involve significant government intervention.

In contrast to many existing irrigation schemes, the proposed development is to be initially characterised by the involvement of only three large and reputable organisations; Wesfarmers, Marubeni and the Water Corporation; and a relatively small number of small scale operators. This factor has been taken into consideration in the development of a conceptual framework for environmental management, in addition to the analysis of existing environmental frameworks in operation in Australia (see Section 16.3), and the distinctive characteristics of the proposed development (see Section 16.1).

It is the view of Wesfarmers–Marubeni and the Water Corporation that the nature of the proposed development, including the proposed industry structure, and the perceived key elements of an effective environmental management framework (see Section 16.1) lend themselves to industry self-management.

The environmental management framework proposed by Wesfarmers–Marubeni and the Water Corporation is considered to be an effective means of managing all environmental issues in relation to the proposed development. The proposed framework would clearly outline responsibilities and accountabilities of all industry participants, be self-funding, would facilitate community input, and would readily accommodate any future assignment of asset ownership. At the same time, the proposed framework would provide a transparent means for the reporting of compliance with relevant legislation. Details of the proposed framework are in the following sections.

16.4.2 Outline of the Proposed Environmental Management Framework

The Proposed development would comprise the following core industry activities:

- the development and operation of irrigated farmland, predominantly for the purpose of growing sugarcane;
- the development and operation of a raw sugar mill;
- the development and operation of irrigation and drainage infrastructure;
- the development and operation of storage and handling facilities at Wyndham.

It is envisaged that in the first instance any environmental conditions would be assigned to Wesfarmers–Marubeni and the Water Corporation. It would follow that each of the asset owners would have environmental responsibilities and obligations under the relevant environmental legislation. Furthermore, any Project water allocation would be made in accordance with the Interim Water Allocation Plan (Section 5.2 refers). The Interim Water

Allocation Plan, prepared by the Waters and Rivers Commission, is currently the subject of analysis by the EPA.

The three core industry activities would be interrelated. Key interrelationships are as follows:

- Irrigation water would be supplied by the owner of the irrigation and drainage infrastructure to the operator of the irrigated farmland, and some stormwater runoff from farmland would be accommodated by the drainage infrastructure.
- The sugar mill would require process cooling water. The cooling water would be sourced from the irrigation infrastructure, and it is envisaged that the cooling water would be reinjected into the irrigation system after utilisation in the milling process.
- Sugarcane would be supplied to the sugar mill from the irrigated farmland.

Wesfarmers–Marubeni and the Water Corporation propose that an entity is established to shoulder the operational aspects of ongoing environmental management in relation to the proposed development on behalf of the industry participants. The proposed entity, or Environmental Management Entity (EME), would be owned by the industry participants, and would provide environmental management services to the owners. Key features of the proposed EME would be as follows:

- The EME would be wholly owned by the industry participants, including all three core industry participants.
- The key objective of the EME would be the management of environmental issues within the entire Project Area, on behalf of the industry participants.
- The EME would be responsible for aspects such as ongoing monitoring, analysis, and reporting on behalf of industry within the proposed development—but legal responsibility for environmental compliance would rest with the individual asset owners.
- The EME would be the focal point for community input in relation to the Project environmental issues in relation to the proposed development.
- The EME would be resourced by the industry participants within the proposed development.
- Shareholder rights and obligations with respect to the EME would be assigned to any new asset owner in parallel with any future asset ownership transfer.

Ownership Structure of the EME

The EME would be formed prior to the commencement of any development works associated with the proposed development. Founding shares in the entity would be issued to the core industry asset owners, including owner/operators of the farmland, the sugar mill, and the irrigation and drainage infrastructure. In the case of the farmland, shares may be allocated on the basis of landholdings.

It is envisaged that the EME would have a chairperson, and a board of directors. Directors would comprise nominated representatives of the shareholders, and directors may also include representatives from the broader community (see Community Input below).

Objectives of the EME

The principle objectives of the proposed EME would be as follows:

- to protect and, where appropriate, improve the physical and biological environment of the Project Area in relation to the proposed development;
- to monitor the compliance of asset owners with relevant legislation, statutory approvals, and the EMP;
- to provide an adequate level of reporting to external bodies of environmental management within the Project Area.

Operations of the EME

It is envisaged that the EME would have an executive division, situated within the Project Area, with appropriate facilities and resources to carry out the activities on behalf of the asset owners as detailed below:

- finalise the EMP for the proposed development, which would take into account the commitments made by Wesfarmers–Marubeni and the Water Corporation in this ERMP/draft EIS, any environmental conditions set by the Minister for the Environment, and any other relevant statutory approvals (Section 16.5 refers);
- obtain approval for the EMP from the Minister for the Environment or the EPA as required;
- provide continuous technical support for the implementation of the EMP;
- prepare any other documentation required to obtain clearance of environmental conditions set by the Minister for the Environment;
- co-ordinate management activities in the conservation areas and buffer zones within the Project Area;
- monitor and report the environmental performance indicators identified in the EMP;
- identify and implement any corrective actions required to mitigate environmental impacts identified through the monitoring programme;
- review results of the monitoring programme in conjunction with the EMP on a regular basis, to determine whether environmental management measures are effective in mitigating environmental impacts;
- implement field audits of operator activities to ensure compliance with the EMP;
- periodically review and revise the EMP as appropriate;
- co-ordinate staff training programmes in relation to environmental issues on behalf of industry within the proposed development;
- reporting of environmental compliance with commitments made by Wesfarmers–Marubeni and the Water Corporation under this ERMP/draft EIS, and relevant statutory requirements on behalf of shareholders, in a consolidated industry-wide format.

Community Input

It is envisaged that the EME would be the repository of a broad range of environmental information relevant to the proposed development, and would be the avenue through which further information could be sought if considered necessary. The EME would be the 'human face' of the management of environmental issues in the Project Area.

The EME would provide the community with a focal point for interaction regarding environmental issues relevant to the proposed development, either through the board of directors, or the company management.

It is envisaged that community interaction with the EME could be via two avenues;

- direct consultation with the EME, and/or;
- community representation on the Board of the EME.

Resourcing of the EME

The EME would be fully resourced by the industry participants. It is envisaged that the resourcing requirements would include appropriate facilities located within the Project Area to perform the operations of the EME, and an ongoing operating budget for salaries, materials, consumables, and expenses associated with the continuous monitoring and reporting programme. Funding would be raised from industry for all capital and operating cost requirements of the EME.

Future Transfer of Asset Ownership

An important aspect of the environmental management framework is the implication, if any, of future transfer of asset ownership.

In the early years, it is planned to transfer land to independent farmers. Also, over time, it is conceivable that part or all of the Wesfarmers–Marubeni corporate sugarcane plantation may be transferred to third parties. Furthermore, it is conceivable that ownership of the sugar mill and/or ownership of the irrigation and drainage infrastructure may change over time.

It is the view of Wesfarmers–Marubeni and the Water Corporation that the proposed environmental management framework would be robust with respect to future transfer of asset ownership.

As stated previously, it is envisaged responsibility for legal and statutory environmental compliance would rest with the relevant individual asset owners. Assignment of an interest in any asset, in part or whole, would involve the transfer of legal or statutory environmental compliance responsibility to the new owner. It is also planned that shareholder rights and obligations with respect to the EME would be stapled to the asset, and flow with any asset transfer.

A diagrammatic representation of the proposed ownership, operating structure and resourcing of the EME is presented in Figures 16.2, 16.3 and 16.4.

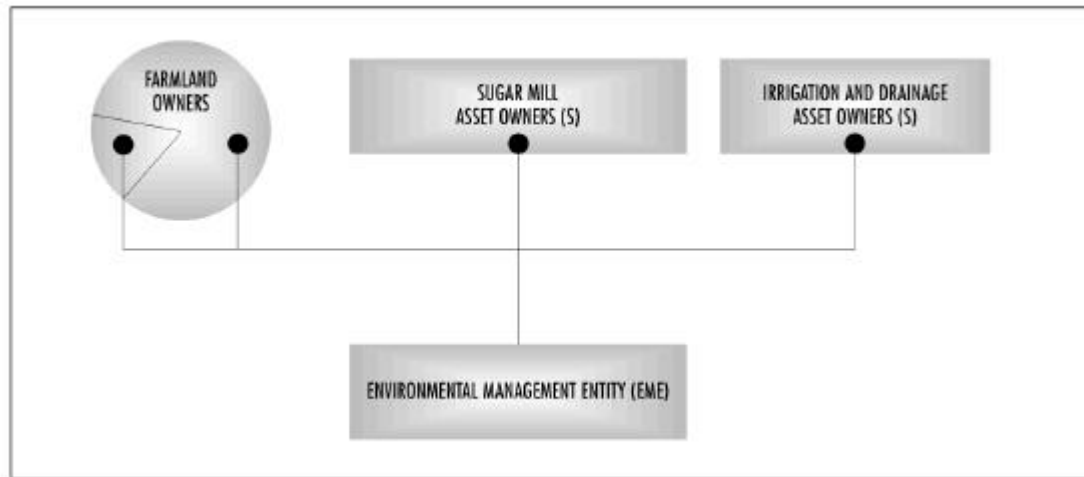


Figure 16.2 Ownership of the proposed Environmental Management Entity

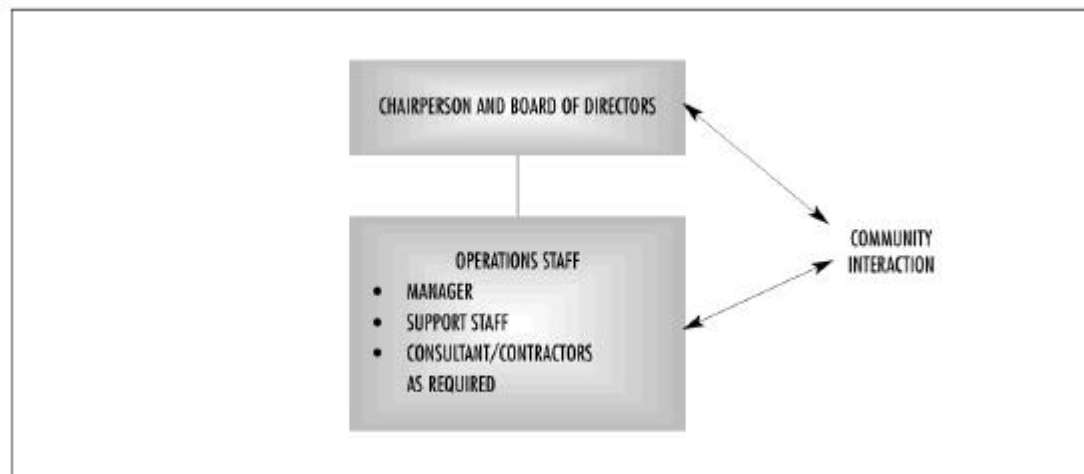


Figure 16.3 Structure of the Environmental Management Entity

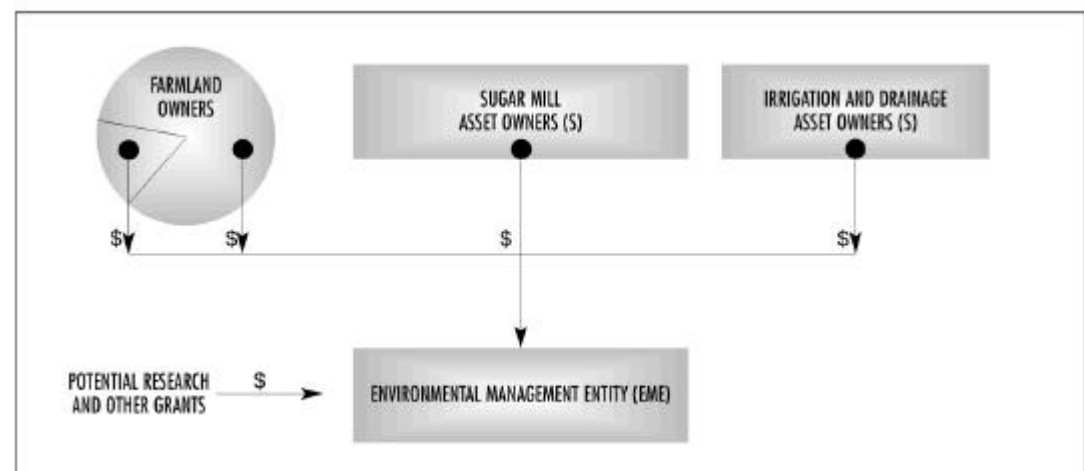


Figure 16.4 Resourcing of the Environmental Management Entity Operations

16.5 ENVIRONMENTAL MANAGEMENT PLAN

The Environmental Management Plan (EMP) would be finalised prior to any development works to monitor and manage any potential environmental impact associated with the proposed development. The EMP would consider both construction and operation activities. An outline of the EMP has already been prepared (Appendix O) and finalisation of the EMP would be the responsibility of the EME, on behalf of Wesfarmers–Marubeni and the Water Corporation.

The finalised EMP would formally enshrine environmental commitments made within this ERMP/draft EIS, and ultimately incorporate any environmental conditions imposed on the proposed development by the Minister for the Environment. The EMP would also highlight any extracts of State, Territory or Commonwealth legislation relevant to the ongoing management of environmental issues in relation to the proposed development. Also, and prior to finalisation, the EMP would be the subject of a public review.

A summary of the process for finalisation of the EMP is as follows:

- assessment of the outline EMP (Appendix O of this ERMP/draft EIS) by the EPA and DLPE;
- the imposition of any environmental conditions by the Minister for the Environment;
- the granting of operational licenses and any associated conditions;
- consolidation by the EME of all the abovementioned points in a draft EMP;
- public review of the draft EMP;
- finalisation and approval of the EMP following the receipt of public comments.

Following finalisation of the EMP, it is envisaged that the EMP would be reviewed and updated on a periodic basis, say every 3 to 5 years. The purpose of the periodic review would be to ensure the EMP reflected current trends in environmental standards and any interim changes in relevant legislation.

16.6 ENVIRONMENTAL COMPLIANCE/REGULATORY REVIEW

As detailed in previous sections, the proposed environmental management framework is based on the principle of self-management. It is recognised by Wesfarmers–Marubeni and the Water Corporation that self-management should be sufficiently transparent so as to provide an appropriate level of comfort to parties external to the proposed industry, such as relevant government agencies and community groups, with respect to environmental compliance and performance.

A comprehensive EMP is to be prepared prior to the commencement of any development works (section 16.5 refers). It is proposed that the monitoring of the implementation of the EMP is to be the responsibility of the EME, on behalf of the industry participants. The frequency of the monitoring process would relate to the particular aspect of the EMP being monitored, but in a conceptual sense the monitoring process could be considered continuous.

The results and interpretation of the monitoring process would be reported on an annual basis by the EME, on behalf of the industry participants. The annual report would detail actual environment performance against the environmental performance targets detailed in the EMP, and would be made readily available to the industry participants. The annual

report would also be made available to relevant government agencies and possibly to other organisations and community interest groups.

The annual report would provide a transparent means for the ready identification of compliance by the industry with all aspects of the EMP. The report would also articulate proposed remedial measures in any aspect of environmental management in which the performance did not meet expectations detailed in the EMP. The proposed remedial measures would be developed by the EME in conjunction with the relevant asset owners. Any asset owner found to be in breach of environmental conditions, including any aspect of the EMP, would be exposed to action under the *Environmental Protection Act 1986* (WA) and the *Environmental Assessment Act 1994* (NT).

A secondary mechanism for compliance would be through the supply of water to farms and the sugar mill. The Water Corporation would be the supplier of irrigation water and drainage services. As detailed in Chapter 5, the provision of water to the Project Area would be subject to:

- a volume allocation as stipulated in a Water Allocation Plan prepared by the Water and Rivers Commission;
- a water licence issued to the Water Corporation by the Water and Rivers Commission.

Prior to formalisation, both the water allocation and the water licence are to be reviewed by the EPA. It follows that any environmental conditions attached to either the water allocation and/or the water licence would be transferred from the Water and Rivers Commission to the Water Corporation under the terms of the allocation and the licence. Any breach of environmental conditions associated with water supply and drainage would expose the Water Corporation to action under the *Environmental Protection Act 1986*.

In summary, the compliance of all industry sectors with the EMP and environmental conditions would be continuously monitored, and reported in a transparent way on a regular basis. Also, whilst the onus of compliance will rest with the industry participants, all industry sectors would have legal responsibility to comply with environmental legislation, relevant to the activities of the respective industry sectors.

16.7 ALTERNATIVE OPTIONS FOR MANAGEMENT

A summary of various irrigation management frameworks currently in practice throughout Australia was presented in Section 16.3. The frameworks were assessed by Wesfarmers–Marubeni and the Water Corporation, in conjunction with the distinctive characteristics of the proposed development, to formulate conceptual options for a suitable environmental management framework for the proposed development. The alternative options were used as a basis for the environmental framework presented in Section 16.4.2. A summary of the alternatives that were considered follows.

Alternative 1—'Do nothing'

Alternative 1 would allow for the proposed development to proceed without any overall coordination of environmental management.

At face value, Alternative 1 would appear to be academic, and contravene current community expectations with respect to the responsible environmental management of significant development initiatives. However, it should be noted that land clearing for the

purposes of broadacre agriculture has not always attracted input from the EPA in the past, and the environmental approval processes associated with the development of sugar mills in Australia in recent years have not been as rigorous as the environmental approval process stipulated for the proposed development.

Despite the abovementioned comments, Alternative 1 has been discounted for application to the proposed development. It is the view of Wesfarmers–Marubeni and the Water Corporation that Alternative 1 does not allow for the identification and coordination of environmental management, monitoring and remediation requirements, nor does it accommodate for the responsibility of funding the environmental management. Therefore, it does not achieve the objectives identified for the environmental management framework.

Alternative 2—Government Agency Management

Under Alternative 2, a new or existing Government agency would manage the environmental issues in relation to the proposed development.

The responsibilities the Government agency in relation to the proposed development would need to be clearly defined. Also, a legal basis may need to be developed to provide funding and administer resources. This approach may require amendments to existing legislation or preparation of new legislation. The Government agency would have to accept responsibility for the environmental conditions and commitments, or it would have to establish a mechanism for third party implementation.

This option was considered to be unsuitable for the proposed development as it may detract from the rights and responsibilities of the developers and operators of the proposed development, and may result in sub-optimal performance of the proposed development.

Alternative 3—Management Entity based on Landholdings

Alternative 3 was based upon the formation of a management entity, with shareholdings in the entity issued in proportion to landholdings.

Whilst this alternative may address certain aspects of land management, it was considered deficient with respect to the integration of water management issues. Under Alternative 3, the demarcation of environmental responsibility between the landholders and the owner of the irrigation and drainage infrastructure may be unclear. For example, the management entity may identify, as a result of a groundwater monitoring programme, groundwater remediation measures and attribute the cause of the problem to the owner of the irrigation and drainage infrastructure. If the owner of the irrigation and drainage infrastructure attributed the cause of the groundwater problem to the landholder, there may be potential for a stalemate with respect to any remediation measures.

This alternative was discounted from consideration in favour of a framework which had a ‘whole of industry’ approach to management of the environmental issues. Wesfarmers–Marubeni and the Water Corporation consider that a ‘whole of industry’ framework would have the advantages detailed in Section 16.4.

17 Environmental management commitments

This chapter contains a listing of the key commitments made in this ERMP/draft EIS relating to environmental management. These key commitments are listed in Table 17.1 together with other information as required by the guidelines (Appendix A) for this document.

Table 17.1 Summary of key commitments relating to the environmental management

Relevant ERMP/EIS Section	Commitment	Timing	Responsibility	Objective	Action	Further consultation	Compliance Criteria
Chapter 1—Project Objectives and Background							
1.5.1	The ongoing management proposed for the Project's conservation areas would include research focussed at improving environmental management systems for these areas.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, Water Corporation and independent farmers.	Improve knowledge of environmental management.	By including the requirement for research in the EMP.	CALM and PWCNT.	–
Chapter 2—The Existing Ord River Irrigation Area							
2.4.2	A proactive groundwater management strategy is proposed as part of the Project. This strategy seeks to manage groundwater levels from project inception to ensure the sustainability of irrigated agriculture on the Project Area. Key elements of the strategy are as follows:						
	engineering design standards would comply with current best practice for all irrigation channels and regulating storage's intended to convey or store water for prolonged periods. These design standards would specify the minimum thickness and compaction levels of the clay lining systems provided to minimise accessions to groundwater;	Before construction.	Water Corporation.	Minimise accessions.	By implementing appropriate design, material selection and construction method and monitor.	–	Maximum seepage rate of 2 mm/d.
	regulating storage's would be sited to areas that naturally contain greater surface thickness of the less permeable Aquitaine clays;	Before construction.	Water Corporation.	Minimise accessions.	By implementing appropriate design, material selection and construction method and monitor.	–	Maximum seepage rate of 2 mm/d.
	drains for stormwater runoff would be designed with broad channel inverts to minimise excavation, thereby containing the channel inverts where possible in the naturally occurring less permeable surface soils;	Before construction.	Water Corporation.	Minimise accessions.	By setting appropriate design standard.	–	–
	comprehensive supervision and quality assurance procedures would be adopted to ensure that the design intent is fulfilled during construction;	Construction.	Water Corporation.	Minimise accessions.	By implementing requirements of ISO standards or similar.	–	ISO standards or similar.
	crop watering strategies that maximise the water uptake by crops and minimise the water loss to groundwater would be utilised;	Operation	Wesfarmers–Marubeni and independent farmers.	Minimise accessions.	By measures such as measuring soil moisture.	AGWEST.	–
	groundwater levels would be controlled via the utilisation of bores and subsoil drains;	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Minimise impacts on proposed land use.	By use of bores and subsoil drains.	WRC and DLPE.	–
	a comprehensive monitoring programme for groundwater levels and quality, and use of the collected data to modify management practices would be practiced.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Monitor groundwater levels.	By regular monitoring of observation wells.	WRC and DLPE.	WRC and DLPE.
Chapter 3—Description of the Project							
3.2.4	Wesfarmers–Marubeni and the Water Corporation would prepare an EMP for the Project upon receipt of environmental approval. The EMP would incorporate all the requirements of the commitments and conditions that apply to the Project and be prepared in consultation with the DEP, the Department of Lands, Planning and Environment and other regulatory authorities. Compliance with the EMP would be mandatory for all landowners and occupiers within the Project Area.	Before construction.	Wesfarmers–Marubeni and the Water Corporation.	Effective environmental management.	By preparing and implementing the EMP.	EPA and DLPE.	To satisfaction of EPA and DLPE.
3.3.1	Precision farm water management techniques would be developed for the Project Area and their adoption would be required under the proposed EMP. It is anticipated that these techniques would be based upon measurement of actual crop water use in the soil profile to determine the timing and magnitude of irrigation applications.	Operation.	Wesfarmers–Marubeni and independent farmers.	Minimise groundwater accessions.	By measures such as measuring soil moisture.	AGWEST.	–

Relevant ERMP/EIS Section	Commitment	Timing	Responsibility	Objective	Action	Further consultation	Compliance Criteria
3.3.2	All farms in the Project Area would be developed with irrigation tailwater management systems. Irrigation tailwater is the water leaving the end of the furrows during watering and is unavoidable if uniform water application to the crop is desired. A conceptual tailwater management system proposed for use in the Project Area is shown in Figure 3.3 and would consist of the following elements: - tailwater ditch that collect tailwater from the furrows and deliver it to a tailwater dam; - tailwater dams. The volume of these dams would be optimised during detail design with the objective being to minimise discharges of irrigation tailwater during the dry season. As a minimum, the tailwater dam capacity would be sufficient to provide the specified first-flush stormwater retention capacity (see Section 5.5.2) for the Project—12 mm of rainfall runoff for sugarcane farms and 25 mm of rainfall runoff from other farms; - tailwater return pumps and pipelines that would return irrigation tailwater to the farm head ditch or to other intermediate points in the farm irrigation system for application to the crop. The tailwater return pumps would be set to operate at partial filling of the dam, thereby reducing the volume of tailwater requiring storage.	Construction.	Wesfarmers–Marubeni and independent farmers.	Virtually eliminate discharges of irrigation tailwater during the dry season.	By constructing and operating the tailwater return system.	–	To satisfaction of DEP and DLPE.
3.4.2	Regimes of chemical and fertiliser usage, in terms of type, timing and method of application would be incorporated into the EMP to be developed for the Project Area (Section 3.2.4). These restrictions would as a minimum include: - pesticide application in accordance with the annual spray calendar prepared for the ORIA; - the use only of chemicals that are approved by the Governments of Western Australia and the Northern Territory; - the successful completion of training for farm staff required to spray chemicals; - commercial spray operators being required to be fully accredited under a national standards system; - a ban on the use of endosulfan during the wet season (November to March) and at other times when the crop areas have free-standing water in either the furrows or tail drains; - application of endosulfan to comply with the NRA review recommendations (see Section 2.3.1), and substitution of more benign insecticides for endosulfan wherever possible.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Minimise use of pesticides.	By incorporating into EMP and implementing.	AGWEST.	NRA recommendations and National Standards.
3.5.1	The supply channels would be open excavations with sloping sides (Figure 3.7). The soil from the excavation would be used to form compacted banks on each side of the channels, and the banks would be around 4–5 m wide at their crest. Compacted clay channel lining would be provided where the channel excavation would be constructed in more permeable soils. This lining would be at least 0.5 m thick over the bed and the lower 1–2 m of the channel batters.	Construction.	Water Corporation.	Minimise groundwater accessions.	By implementing design and construction standards and monitoring.	–	Maximum seepage rate of 2mm/d.
3.5.2	Current planning is based upon the use of wider, shallower drains than were built in ORIA Stage 1. This approach would minimise seepage to groundwater by locating the channel inverts in the less permeable surface soils. Where deeper drains are required, the excavated surface of the drain would be compacted to minimise seepage.	Construction.	Water Corporation.	Minimise groundwater accessions.	By implementing design and construction standards and monitoring.	–	–
3.7.3	Emissions from the boiler would be passed through a scrubber to achieve a maximum particulate discharge of 32 kg/h from the 40 m high chimney. Bagasse firing would be a complete combustion process with excess oxygen available at all times. The process effluent would be treated in a biological treatment plant combining activated sludge and anaerobic processes. The treated effluent, with a BOD level of less than 20 mg/L, may be used as irrigation water directly on to canefields near to the mill. The boiler blow-down would be combined with the process effluent for disposal.	Operation.	Wesfarmers–Marubeni.	Avoid air and water pollution.	By implementing design and construction standards and monitoring.	DEP.	National standards for emissions from stationary sources.
3.9.1	Trucks would be operated and maintained to meet the requirements of relevant noise abatement legislation.	Operation.	Wesfarmers–Marubeni.	Avoid nuisance noise.	By maintenance of vehicles by haulage contractors.	DEP and DLPE.	National standards for noise emissions from mobile sources.

Relevant ERMP/EIS Section	Commitment	Timing	Responsibility	Objective	Action	Further consultation	Compliance Criteria
3.9.1	Public roads would be designed to the appropriate national road design standards in order to provide an acceptable level of safety for the cane transport operations and other road users.	Before Construction.	Wesfarmers–Marubeni.	Design safe roads.	By adopting national road design standards.	Main Roads WA and Department of Transport and Works.	National standards.
3.9.2	All farm requirements would be transported and stored in accordance with regulatory requirements, including impervious bunding of storage areas as appropriate.	Operation.	Wesfarmers–Marubeni and independent farmers.	Avoid pollution.	By fulfilling regulatory requirements.	Minerals and Energy (WA & NT).	NRA Recommendations and national standards.
3.10	In areas where reserve widths significantly greater than those required for construction, only the sections necessary for construction and future maintenance purposes would be cleared.	Construction.	Wesfarmers–Marubeni and the Water Corporation.	Avoid excessive clearing.	By including requirement in construction contracts and monitoring.	–	–
3.10	Construction of roads and the irrigation infrastructure would require access to local sources of suitable clay, sand and gravel material. Borrow pits would be selected in accordance with Aboriginal cultural and heritage considerations of the land and operated as far as practicable with a view to minimising erosion, damage to surrounding vegetation and visual impact. Once construction is completed, areas no longer required would be rehabilitated by a combination of contouring, slope stabilisation, topsoil spreading and seeding.	Construction.	Wesfarmers–Marubeni and the Water Corporation.	Achieve appropriate rehabilitation.	By including requirement in construction contracts and monitoring.	Miriuwung and Gajerrong people, CALM, PWCNT and the Shire of Wyndham — East Kimberley.	To satisfaction of CALM and PWCNT.
3.10	Sewage and refuse from the camp would be treated and disposed of in a manner approved by the relevant public health authorities of the Northern Territory.	Construction.	Wesfarmers–Marubeni and the Water Corporation.	Avoid pollution.	By including requirement in construction contracts and monitoring.	NT Dept of Health.	To satisfaction of NT Department of Health.
3.10	Few construction-related environmental issues are envisaged due to the remoteness of the Project Area from residential areas. An exception relates to the proximity of a section of the proposed M2 Channel, which in some areas is within 300 m of residences. The following measures would be employed at these locations to minimise nuisance from construction equipment: - Construction activities would be restricted to daylight hours. - Prior to use, all equipment would be checked to ensure that silencing equipment had been fitted and was in good working order. Local residents would be advised of the nature of the activities to be undertaken and of their duration, particularly if blasting were required to remove rock.	Construction.	Water Corporation.	Minimise disturbance and nuisance to existing residents.	By including requirement in construction contracts and monitoring.	Local residents and the DEP.	Noise abatement regulations.
Chapter 4—Physical Environment							
4.5.2	Soil erosion in the Project Area would be controlled by a combination of the following management strategies: - controlling drainage by providing levee banks to prevent floodwaters entering the developed area; - grading land on farms to gentle slopes to minimise stormwater runoff velocities; - sizing and designing receiving drains to accommodate anticipated flow regimes; - providing buffer zones on both sides of watercourses to allow riparian vegetation to continue to stabilise soils in these areas; - rehabilitating disturbed areas; - as soon as possible following disturbance during construction; - by formulating and implementing appropriate rehabilitation plans and programmes including topsoil stripping and stockpiling, land preparation, and reseedling with local native species to facilitate regeneration of disturbed areas; - managing crops in such a way that crop cover of the soil is maximised, particularly during the wet season when erosive rainfall events may occur.	Construction.	Wesfarmers–Marubeni and the Water Corporation.	Minimise soil erosion.	By including rehabilitation requirements and plans in construction contracts and monitoring.	Commissioner of Soil and Land Conservation (WA) and DLPE.	To satisfaction of Commissioner of Soil and Land Conservation (WA) and DLPE.
		Operation.	Wesfarmers–Marubeni and independent farmers.	Minimise soil erosion.	By maximising crop cover.	–	–
4.5.3	Drainage waters leaving farms would first pass through farm drains and tailwater return systems that would settle and collect larger soil particles, such as coarse silts and sands. Farm maintenance would include regular desilting of these drains and return of the collected material to the cropped area.	Operation.	Wesfarmers–Marubeni and independent farmers.	Minimise water pollution.	By regular desilting of tailwater return systems.	–	Quality (suspended solids) of drainage waters to be in natural range of Keep River.

Relevant ERMP/EIS Section	Commitment	Timing	Responsibility	Objective	Action	Further consultation	Compliance Criteria
4.5.4	Long-term monitoring would be undertaken to ascertain any changes to surface and subsoil salinity and sodicity resulting from the proposed irrigation practices, for example by assessing sodium adsorption ratio, ESP and electrical conductivity levels. Alternative management measures would be investigated and trialled if the monitoring should detect an increase in subsoil sodicity levels sufficient to threaten the long-term sustainability of the Project. The converse scenario is also a possibility in that monitoring may indicate that a lower leaching fraction to that currently proposed may be acceptable to control salinity and sodicity. In this case, the irrigation practices would be modified to reduce the accessions to groundwater, thereby conserving water and reducing or postponing the Project's groundwater management requirements. Within the irrigation area, the chemical status of the soil would also be routinely assessed as a component of ongoing management. This would include regular assessment of soil chemistry, including macro- and micronutrient status, organic matter content and pH. Records of soil tests would be maintained to develop a history of soil chemical and physical status.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni and independent farmers.	Avoid significant increases in subsoil salinity and sodicity levels.	Undertake monitoring and advise farmers of optimal watering strategies.	AGWEST.	Target sub-soil ESP of 15.
Chapter 5—Surface Water							
5.4.1	Localised areas of high water velocity may occur at structures constructed across natural watercourses, such as the siphon and bridge crossings of Knox Creek and the Keep River. Appropriate erosion protection measures such as stone pitching and bridge abutments would be developed for these areas as part of the detail design for the Project.	Construction.	Wesfarmers–Marubeni and the Water Corporation.	Minimise erosion of watercourses.	By implementing protective measures at watercourse crossings.	–	To satisfaction of Commissioner of Soil and Land Conservation (WA) and DLPE.
5.4.1	Monitoring of erosion along all watercourses, including constructed drains would be undertaken as part of the EMP for the Project. Localised management of any erosion would be undertaken on an as-needed basis by the Environmental Management Entity that would be established as part of the Project	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Minimise erosion of water courses.	By monitoring and implementing remedial measures as needed.	–	–
5.5.1	Management of sediment during construction would involve a combination of the following measures: • wherever practicable, restricting ground-disturbing operations to the dry season; • restricting ground-disturbing operations to the minimum area required to facilitate construction; • collecting and storing for future use any topsoil from areas to be disturbed; • installing and maintaining temporary sediment traps downstream of any areas to be disturbed; • progressive clearing, developing and rehabilitating, wherever possible using locally won topsoil, of any areas that are no longer going to be disturbed.	Construction.	Wesfarmers–Marubeni and the Water Corporation.	Minimise sediment load to receiving waters.	By incorporating requirements into construction contracts and monitoring.	Commissioner of Soil and Land Conservation (WA) and DLPE.	To satisfaction of Commissioner of Soil, Land Conservation (WA) and DLPE.
5.5.1	Monitoring of water quality in the receiving watercourses would also be undertaken during construction.	Construction	Environmental Management Entity on behalf of the Wesfarmers–Marubeni and the Water Corporation.	Monitor and advise on effective control measures.	By implementing requirements of EMP.	–	Natural range of receiving waters.
5.5.1	Fertilisers or chemicals would not be applied to cropped areas when the first-flush basin capacity is not available.	Operation.	Wesfarmers–Marubeni and independent farmers.	Minimise water pollution.	Only apply fertilisers and pesticides when first flush basin capacity available.	–	Nutrients within natural range for receiving waters. Pesticides within national guidelines to maintain aquatic ecosystems in receiving waters.
5.5.1	The storage capacity of the first-flush systems would be maintained through regular inspection and removal of sediment.	Operation.	Wesfarmers–Marubeni and independent farmers.	Maintain water management systems.	Inspect and maintain first flush systems.	–	75% of design storage capacity maintained.
5.5.2	Sugarcane has a low requirement for pesticides to grow successfully in the ORIA. However, the management measures that would be adopted for the Project to minimise the effects of any spray drift would be as follows:	Operation.	Wesfarmers–Marubeni and independent farmers.	Minimise pesticide levels in receiving waters.	As committed.	AGWEST.	National guideline values for pesticides for maintenance of aquatic ecosystems.

Relevant ERMP/EIS Section	Commitment	Timing	Responsibility	Objective	Action	Further consultation	Compliance Criteria
	• adoption, where appropriate for the crops being grown, of the integrated pest management strategy developed by AGWEST for the ORIA (see Section 2.3.1) to minimise the amount of pesticides used; • strict control on the use of pesticides, including mandatory adoption by all farmers of the spray calendar developed annually for ORIA Stage 1; • minimisation of the use of aerial spraying, by using tractor-based spraying to the maximum extent possible; • avoidance of unsuitable weather conditions such as surface temperature inversions and unstable conditions during aerial spraying whenever possible; • utilisation of a larger droplet size settings for spray equipment during aerial spraying; • a requirement that all commercial spray operators be accredited to a national registration programme.						
5.5.2	Management measures that would be adopted for the Project to minimise the effects of airborne dust include: • provision of dedicated on-farm access tracks that would not have agricultural chemicals applied directly to them; • wherever possible, adoption of ‘minimum tillage’ farming practices.	Operation.	Wesfarmers–Marubeni and independent farmers.	Minimise spread of pesticides by minimising dust.	As committed.	AGWEST.	National guideline values for pesticides for maintenance of aquatic ecosystems.
5.5.4	Control of aquatic weeds in the irrigation channels and balancing storage dams would be by a combination of mechanical weed removal and periodic dosing with a chemical such as acrolein. The latter is currently used for the control of aquatic weeds in the irrigation channels in ORIA Stage 1. Chemical management would be in accordance with best-practice procedures as outlined below: • emptying the channel, locking offtakes, erecting warning signage and notifying farmers prior to injection of the chemical; • releasing a known flow of water to obtain a water depth of approximately 0.5 m into the channel and releasing the chemical from a controllable release point to maintain an initial concentration (15 ppm in the case of acrolein); • releasing a marker dye to denote the chemical front; • shutting flow to the channel and holding the chemical in the channel for a minimum of forty-eight hours before diluting by release of additional water and use of the water for irrigation; • monitoring the watercourses downstream of the Project Area for acrolein and if detected, review the above procedure in conjunction with the Water and Rivers Commission and the DLPE.	Operation.	Water Corporation.	Manage chemical use and minimise discharges to receiving waters.	As committed.	WRC and DLPE.	National guideline values for maintenance of aquatic ecosystems.
5.6.1	As a consequence of the predicted endosulfan concentration being of similar magnitude to the recommended limit, a precautionary approach of adopting interim restrictions is proposed on the use of endosulfan in the Project Area. The interim restrictions would require each application of endosulfan to receive prior approval from the Environmental Management Entity that would be established in conjunction with the Project (see Chapter 16). The interim restrictions would include monitoring of farm drains, tailwater return systems and drainage flows to confirm the effectiveness of the proposed management measures.	Operation.	Environmental Management Entity on behalf of independent farmers.	Manage endosulfan levels in receiving waters to below guideline levels	Obtain prior approval of each application of endosulfan and monitor.	AGWEST.	National guideline values for endosulfan for maintenance of aquatic ecosystems.
5.6.3	Water quality monitoring would form an important component of the environmental management programme proposed for the Project. Data collected by the monitoring programme would be assessed regularly in conjunction with management practices with the aim of minimising impacts on the receiving environment.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Provide data for improved management.	By implementing EMP.	WRC and DLPE.	To satisfaction of WRC and DLPE.

Relevant ERMP/EIS Section	Commitment	Timing	Responsibility	Objective	Action	Further consultation	Compliance Criteria
Chapter 6—Groundwater							
6.5.5	Groundwater monitoring for the Project would commence with delineation drilling across the interpreted position of the palaeochannel aquifers in order to define their actual position beneath the irrigation area. An extensive network of groundwater monitoring bores would also be installed within and adjacent to the irrigation area prior to the commencement of irrigation. This network would include bore transects aligned perpendicular to the Keep River and Sandy Creek to acquire additional data for the better understanding of the river–groundwater interactions, and the establishment of monitoring bores adjacent to Milligan Lagoon. Groundwater samples would be collected during the delineation drilling to quantify the vertical and horizontal water quality distribution.	Construction.	Wesfarmers–Marubeni and the Water Corporation.	Confirm parameters adopted for groundwater modeling.	Conduct further groundwater monitoring.	WRC and DLPE.	To satisfaction of WRC and DLPE.
6.5.5	Test dewatering bores would be installed and tested to confirm aquifer yields and the response of the aquifers to pumping. The data collected by the above programmes would be used to continually update the groundwater model and to optimise the extent and timing of installation of the groundwater management system.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Optimise groundwater management.	Install and operate test bores.	WRC and DLPE.	To satisfaction of WRC and DLPE.
6.5.5	The quality of groundwater adjacent to watercourses would be monitored. The groundwater pumping strategy would include provision for the capture of additional groundwater adjacent to the watercourses if considered necessary.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Maintain health of riparian vegetation.	Monitor groundwater adjacent to watercourse and implement control measures of needed.	WRC and DLPE.	To satisfaction of WRC and DLPE.
Chapter 10—Biological Environment—Impacts and Management							
10.1.3	Any loss of or impairment to, the use of flora or fauna and other resources by Miriung and Gajerrong people would be addressed in an Indigenous Land Use Agreement (ILUA) to be negotiated between the Co-proponents and the Miriung Gajerrong people.	Before construction.	Wesfarmers–Marubeni and the Water Corporation.	Obtain agreement of Miriung Gajerrong people.	By negotiation.	Miriung and Gajerrong people.	Agreement of relevant parties.
10.4.8	To ensure that the existing environmental significance of the Point Spring Nature Reserve is maintained, Wesfarmers–Marubeni and the Water Corporation would cooperate with CALM in implementing its management requirements for the site. The overall responsibility for the management of the reserve would remain with CALM. The conservation area between the proposed farmland and Point Spring Nature Reserve would be managed for the purpose of conservation.	Before construction.	Wesfarmers–Marubeni and the Water Corporation.	Maintain environmental values of Point Spring Nature Reserve.	By providing co-operation as appropriate	CALM.	To satisfaction of CALM.
10.5.1	Permanent monitoring sites for flora, fauna and biodiversity would be established in conservation areas, along ecological corridors and in selected sites in the Project Area. Monitoring would be undertaken on a regular basis with the monitoring parameters clearly defined following consultation with the staff of CALM and the Parks and Wildlife Commission of the Northern Territory.	Before construction and operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Monitor flora, fauna and biodiversity.	As committed.	CALM and PWCNT.	To satisfaction of CALM and PWCNT
10.5.2	To limit any potential for over clearing, all areas designated for construction works would be clearly marked on development maps and on the ground prior to commencement of works. Vegetation clearance would be staged so that areas are cleared only as required. Designated conservation areas and vegetation buffers would be clearly established and monitored to ensure they remained undisturbed. All contractors and consultants would be required to participate in a formal environmental and cultural heritage induction programme on the importance of the natural and social environment.	Before construction.	Wesfarmers–Marubeni and the Water Corporation.	Limit any potential for over clearing and improve environmental awareness.	As committed.	–	–
10.5.2	A fire control strategy and plan would be developed for the farms and for the proposed conservation areas. This would include monitoring areas to determine the need for burning. Advice would be sought from CALM and the Parks and Wildlife Commission of the Northern Territory in the preparation of a Fire Management Plan for the Project Area, including the proposed conservation areas. This plan would take into account community assets, environmental values, fire frequency and season, and the impact that fire could have on human life (e.g. those at risk due to fire).	Before construction.	Wesfarmers–Marubeni and the Water Corporation.	Develop appropriate fire management practices	Be developing a fire control strategy and plan and including it in the EMP.	CALM and PWCNT.	To satisfaction of CALM and PWCNT.

Relevant ERMP/EIS Section	Commitment	Timing	Responsibility	Objective	Action	Further consultation	Compliance Criteria
10.5.3	Mandatory interstate quarantine would be maintained to control weeds from other areas. During construction, all construction machinery would be cleaned of soil and other organic debris prior to being transported to the Project Area. If any Declared Weeds or new plants/weeds were introduced into the Project Area, the Weed Science Section of AGWEST, or the Department of Primary Industries and Fisheries (Northern Territory) would be consulted to ensure compliance with relevant legislation and to ensure implementation of appropriate control measures. Quarantine measures that would be implemented for the control of weeds include the following: - Interstate quarantine would be maintained. - During project development, all construction vehicles would be washed down to the standards required by AGWEST to prevent transportation of soils and/or weeds into the Project Area. A wash-down site would be established at the main entrance to the Project Area. All vehicles entering construction areas, even private cars, would be washed down to remove seeds and soil. - All site vehicles would be site-dedicated as much as possible, thus limiting cross-contamination from outside areas. - If borrow is required, it would be obtained from surveyed weed-free sites.	Before construction.	Wesfarmers–Marubeni and the Water Corporation.	Minimise potential for introduction of weeds to Project Area.	As committed.	AGWEST, Department of Primary Industries and Fisheries, CALM and PWCNT.	To satisfaction of AGWEST and Department of Primary Industries and Fisheries
10.5.5	As required by CALM and the Parks and Wildlife Commission of the Northern Territory, dogs and cats would not be permitted in conservation areas.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Minimised potential for feral pests.	By erection of signs.	–	–
10.5.6	Rehabilitation of any sites disturbed during development would be undertaken progressively using seed species collected from the Project Area. Areas disturbed during development of the infrastructure would be rehabilitated as each stage of the work is completed, particularly those drainage channels designated as conservation-vegetation corridors. Where possible, topsoil would be utilised immediately or removed and stockpiled for later use on disturbed areas. Once the development was complete, the topsoil would be spread over the disturbed areas, allowing seeds and rootstock stored in the soil to germinate and become established. Active reseedling of some areas may also take place. Monitoring of success of rehabilitation would be undertaken.	Construction.	Wesfarmers–Marubeni and the Water Corporation.	Effective rehabilitation of disturbed sites.	By including requirements in construction contracts and monitoring.	Miriuwung Gajerrong people, CALM and PWCNT	To satisfaction of Miriuwung Gajerrong people, CALM and PWCNT.
10.5.7	A seed collection programme would be undertaken before vegetation is cleared. A seed mix appropriate to the area to be rehabilitated would be prepared and scattered over the disturbed areas. Alternatively, seedlings could be germinated and planted out at the commencement of the wet season. Only seeds of plant species endemic to the Project Area would be used in revegetation projects.	Construction.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Effective rehabilitation of disturbed sites.	Seed collection and use in rehabilitation projects.	Miriuwung Gajerrong people, CALM and PWCNT.	To satisfaction of Miriuwung Gajerrong people, CALM and PWCNT.
Chapter 11—Land Use							
11.4.4	It is envisaged that access to locations on the Keep River within the Conservation Area would remain open with designated recreation sites for fishing and picnicking purposes being managed by the Environmental Management Entity. Access to the remainder of the conservation area would be restricted to control erosion and weeds as well as to protect the regeneration of the flora and fauna habitats.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Control erosion and weeds.	By providing designated recreation sites and control access.	Miriuwung Gajerrong people and local recreation groups.	To satisfaction of Miriuwung Gajerrong people and local recreation groups.
11.5.1	Project development would include the erection of signs at strategic locations throughout the Project Area that would advise travelers that access to pastoral leases is restricted.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Avoid unwanted visitors to pastoral leases.	By erection of signs.	Local pastoralists.	–

Relevant ERMP/EIS Section	Commitment	Timing	Responsibility	Objective	Action	Further consultation	Compliance Criteria
Chapter 12—Issues Specific to Miriuwung and Gajerrong People							
12.3	Establish a working relationship with the Aboriginal community and to have consistent, open and honest consultation;	Before construction, during construction and operation.	Wesfarmers-Marubeni, the Water Corporation and Environmental Management Entity.	Ensure that a mutually beneficial working relationship is maintained.	By regular contact by Community Relations Team and formal meetings.	Aboriginal Representative Bodies and the Miriuwung and Gajerrong people.	To satisfaction of the Miriuwung and Gajerrong people.
	Hold regular meetings with Miriuwung and Gajerrong people.	Before construction, during construction and operation.	Wesfarmers-Marubeni, the Water Corporation and Environmental Management Entity.	Ensure people are informed about the Project and to provide a venue for feedback.	By regular meetings.	Aboriginal Representative Bodies and the Miriuwung and Gajerrong people.	To satisfaction of the Miriuwung and Gajerrong people, the EPA and DLPE.
12.4.5	Resolve all Native Title issues by concluding an ILUA with the Miriuwung and Gajerrong people.	Before construction.	Wesfarmers-Marubeni, the Water Corporation, WA and NT Governments.	In order to ensure that Miriuwung and Gajerrong aspirations are met and to ensure that statutory land transfer processes can occur.	By formal negotiations.	Aboriginal Representative Bodies and the Miriuwung and Gajerrong people.	To satisfaction of the NNTT.
12.5.2	Comply with relevant cultural heritage legislation and the aspirations of Miriuwung and Gajerrong people.	Before construction, during construction and operation.	Wesfarmers-Marubeni, the Water Corporation, Environmental Management Entity and independent farmers.	Ensure compliance.	By undertaking cultural heritage assessments.	Aboriginal Representative Bodies, Miriuwung and Gajerrong people, AAPA, HCB and AAD.	To satisfaction of the Miriuwung and Gajerrong people, the AAPA, the HCB and the AAD.
12.5.3	Establish and implement Cultural Heritage Protection Procedures;	Before construction and during construction.	Wesfarmers-Marubeni and the Water Corporation	Ensure protection of cultural heritage sites.	By provide the Procedures to all contractors.	Aboriginal Representative Bodies, the Miriuwung and Gajerrong people, AAPA, HCB and AAD.	To satisfaction of the Miriuwung and Gajerrong people, the AAPA, the HCB and the AAD.
	Undertake archaeological and ethnographic assessments of the Project Area;	Before construction.	Wesfarmers-Marubeni and the Water Corporation	Ensure protection of cultural heritage sites.	By negotiation with Aboriginal Representative Bodies.	Aboriginal Representative Bodies, the Miriuwung and Gajerrong people, AAPA, the HCB and the AAD.	To satisfaction of the Miriuwung and Gajerrong people, the AAPA, the HCB and the AAD.
	Develop a Cultural Heritage Management Plan.	Operation.	Wesfarmers-Marubeni, the Water Corporation and Environmental Management Entity.	Ensure protection of cultural heritage sites.	By involving the Aboriginal Representative Bodies and Miriuwung and Gajerrong people.	Aboriginal Representative Bodies, the Miriuwung and Gajerrong people, AAPA, the HCB and the AAD.	To satisfaction of the Miriuwung and Gajerrong people, the AAPA, the HCB and the AAD.
12.5.8	Excise cultural heritage sites from the Project Area;	Before construction.	Wesfarmers-Marubeni, the Water Corporation, WA and NT Government.	Ensure protection of cultural heritage sites.	By completing cultural heritage assessments.	Aboriginal Representative Bodies, the Miriuwung and Gajerrong people, the AAPA, the HCB and the AAD.	To satisfaction of the Miriuwung and Gajerrong people, the AAPA, the HCB and the AAD.
	Establish 'green access paths';	Before construction.	Wesfarmers-Marubeni, the Water Corporation, WA and NT Governments.	Ensure that Native Title rights are maintained.	By agreement with Government.	Aboriginal Representative Bodies, the Miriuwung and Gajerrong people and relevant Government agencies.	To satisfaction of the Miriuwung and Gajerrong people and relevant Government agencies.

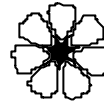
Relevant ERMP/EIS Section	Commitment	Timing	Responsibility	Objective	Action	Further consultation	Compliance Criteria
	Establish the Conservation Area.	Before construction.	Wesfarmers-Marubeni, the Water Corporation, WA and NT Governments.	Ensure protection of cultural heritage sites. Ensure that Native Title rights are maintained.	By agreement with Government.	Aboriginal Representative Bodies, the Miriuwung and Gajerrong people and relevant Government agencies.	To satisfaction of the Miriuwung and Gajerrong people and relevant Government agencies.
12.6.2	Complete an Aboriginal Socio-Economic Impact Assessment.	Before construction.	Wesfarmers-Marubeni and the Water Corporation	Ensure that the Miriuwung and Gajerrong view of the Project is understood and enable the negotiation of an ILUA.	By establishing the Working Group with Miriuwung and Gajerrong people and the Aboriginal Representative Bodies.	Aboriginal Representative Bodies and the Miriuwung and Gajerrong people.	To satisfaction of the Miriuwung and Gajerrong people.
Chapter 13—Air Quality and Noise							
13.2	The main issue associated with dust would be the protection of workers from excessive levels. Earth-moving contracts would be structured to require air-conditioned cabins on earth moving equipment and monitoring of dust levels associated with development activities.	Construction.	Wesfarmers–Marubeni and the Water Corporation.	Protect health of construction workers.	By including requirement to provide air conditioned cabins in construction contracts	–	–
	A dust monitoring programme would be established as part of the EMP and administered throughout the construction and operational phases of the Project, using dust deposit gauges that comply with AS 3580.10.1—1991. Periodic dust monitoring would also be undertaken using portable monitors.	Construction and Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Provide data for management.	As committed.	DEP and DLPE.	–
13.3.2	Some smoke and ash may be generated from burning wood and other vegetation during the construction phase of the Project. The impact of this activity is anticipated to be minimal and temporary, as the burning would be carried out over a relatively short period. The isolation of the Project Area and the relatively sparse coverage of vegetation on the black-soil plains also reduce the significance of this issue. Furthermore, burning practices would be managed to occur at times when prevailing winds would direct smoke and ash away from residential areas.	Construction.	Wesfarmers–Marubeni and the Water Corporation.	Avoid nuisance from smoke and ash fallout.	By including requirements into construction contracts and monitor.	CALM and PWCNT.	–
13.6	Construction works associated with development of the M2 Channel may at times be within 300 m of existing residences. The following management measures would be adopted to mitigate adverse impacts on these residences: - Construction activities would be restricted to daylight hours for all activities within 500 m of an existing residence. - All occupiers of residences within 1 km of construction activities would be advised of the nature and duration of the activities planned, and well in advance of construction commencing. - All construction equipment would be fitted with appropriate silencing equipment and operated in a manner such that the construction activities comply with the Environmental Protection (Noise) Regulations published by the EPA in October 1997. All trucks used for product transport would be fitted with mufflers such that noise levels conform to noise abatement regulations.	Construction.	Wesfarmers-Marubeni and the Water Corporation.	Avoid nuisance to existing residents.	By incorporating requirements into construction contracts and monitoring.	Occupiers of residences within 1 km of construction works.	Noise abatement regulations.
Chapter 14—Public Health							
14.1.3	Management action would be taken in conjunction with the proposed development to reduce the risk of increased infection with arboviruses. These actions would concentrate upon the following activities: - designing and operating the Project so as to reduce the potential for increased mosquito-breeding activity; - implementing education programmes for the Project’s construction and operational workforce on measures that could be taken to reduce their personal risk of infection; - extending the existing monitoring programmes to cover the Project Area.	Before construction, construction and operation.	Wesfarmers–Marubeni, the Water Corporation (to end of construction), Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation (thereafter).	Reduce risk of infection through lower mosquito numbers and public awareness.	As committed.	Health Departments (WA) and (NT).	–

Relevant ERM/EIS Section	Commitment	Timing	Responsibility	Objective	Action	Further consultation	Compliance Criteria
14.2.4	Any usage of chemicals within the Project Area would be in accordance with Commonwealth and State regulations and industry best practice. In order to minimise the potential for spray drift, the application of any chemicals within the Project Area would be from tractor-drawn boom-sprays whenever possible, utilising technology that results in relatively large spray droplets being released close to the ground.	Operation.	Wesfarmers–Marubeni and independent farmers.	Minimise chemicals in the environment.	As committed.	AGWEST Department of Primary Industries and Fisheries.	Commonwealth, State and Territory regulations.
14.2.4	A test kit has been developed by the University of Queensland that allows a rapid assessment of the placement deposit patterns in the field following spray operations. This information can be used to calculate optimum flight lane separations or, if drift is of concern, to determine the extent of drift associated with the spraying operations (Woods and Dorr 1997). This kit, or an equivalent process, would be used by the proposed Environmental Management Entity (Chapter 16) to monitor spraying operations within the Project Area as part of the EMP to be developed for the Project.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Provide data for management.	By incorporating requirements into EMP and implementing.	DEP and DLPE.	–
14.2.4	The low pesticide requirements for sugarcane cultivation combined with the prevalence of heavy soils suggest that contamination of Project Area groundwater by agricultural chemicals is unlikely. Nonetheless, as an additional precaution, groundwater would be tested on a regular basis for all chemicals used in the Project Area to ensure compliance with national drinking water quality guidelines.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Ensure safe drinking water supplies.	As committed.	WRC and DLPE.	National guidelines for drinking water.
Chapter 15 – Community Issues							
15.4.5	Access to the Keep River would be maintained.	Before construction, during construction and operation.	Wesfarmers–Marubeni, the Water Corporation and the Environmental Management Entity.	Ensure public access to the Keep River.	By providing designated recreation sites.	Miriuwung and Gajerrong people and local recreation groups.	To the satisfaction of Miriuwung and Gajerrong people and local recreation groups.
15.5.2	Further public meetings are planned.	Before construction, during construction and operation.	Wesfarmers–Marubeni, the Water Corporation and the Environmental Management Entity.	Ensure the public is kept informed about the development of the Project.	By undertaking consultation with the public.	Local community.	–
Chapter 16—Environmental Management Framework							
16.4.2	Wesfarmers–Marubeni and the Water Corporation propose that an entity be established to shoulder the operational aspects of ongoing environmental management in relation to the proposed development on behalf of the industry participants. The proposed entity, or Environmental Management Entity (EME), would be owned by the industry participants, and would provide environmental management services to the owners. Key features of the proposed EME would be as follows: • The EME would be wholly owned by the industry participants, including all three core industry participants. • The key objective of the EME would be the management of environmental issues within the entire Project Area, on behalf of the industry participants. • The EME would be responsible for aspects such as ongoing monitoring, analysis, and reporting on behalf of industry within the proposed development—but legal responsibility for environmental compliance would rest with the individual asset owners. • The EME would be the focal point for community input in relation to the Project environmental issues in relation to the proposed development. • The EME would be resourced by the industry participants within the proposed development. • Shareholder rights and obligations with respect to the EME would be assigned to any new asset owner in parallel with any future asset ownership transfer. The EME would be formed prior to the commencement of any development works associated with the proposed development. Founding shares in the entity would be issued to the core industry asset owners, including owner/operators of the farmland, the sugar mill, and the irrigation and drainage infrastructure. In the case of the farmland, shares may be allocated on the basis of landholdings.	Before construction.	Wesfarmers–Marubeni and the Water Corporation.	Establish an entity to provide environmental services to the owners.	As committed.	–	–

Relevant ERMP/EIS Section	Commitment	Timing	Responsibility	Objective	Action	Further consultation	Compliance Criteria
16.4.2	The EME would be fully resourced by the industry participants. It is envisaged that the resourcing requirements would include appropriate facilities located within the Project Area to perform the operations of the EME, and an ongoing operating budget for salaries, materials, consumables, and expenses associated with the continuous monitoring and reporting programme. Funding would be raised from industry for all capital and operating cost requirements of the EME.	Before construction and ongoing.	Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Resource the EME.	By providing facilities and funding.	–	–
16.5	The Environmental Management Plan (EMP) would be finalised prior to any development works to monitor and manage any potential environmental impact associated with the proposed development. The EMP would consider both construction and operation activities. An outline of the EMP has already been prepared (Appendix O) and finalisation of the EMP would be the responsibility of the EME on behalf of Wesfarmers-Marubeni and the Water Corporation.	Before construction and ongoing.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Prepare EMP to guide environmental management.	Prepare EMP.	EPA, DLPE, and the Public.	To satisfaction of EPA and DLPE.
16.6	The results and interpretation of the monitoring process would be reported on an annual basis by the EME on behalf of the industry participants. The annual report would detail actual environmental performance against the environmental performance targets detailed in the EMP, and would be made readily available to the industry participants. The annual report would also be made available to relevant government agencies and possibly other organisations and community interest groups.	Operation.	Environmental Management Entity on behalf of Wesfarmers–Marubeni, independent farmers and the Water Corporation.	Provide ready identification of compliance by the industry with the EMP.	Prepare annual reports and make available to industry participants and relevant government agencies.	EPA, and DLPE.	–

APPENDIX A

ERMP/DRAFT EIS GUIDELINES



Northern Territory Government

**Western Australian Environmental Protection Authority/
Northern Territory Department of Lands, Planning & Environment**

Joint Environmental Assessment

**ORD RIVER IRRIGATION AREA STAGE 2
(M2 CHANNEL SUPPLY AREA), KUNUNURRA**

**GUIDELINES FOR AN
ENVIRONMENTAL REVIEW AND MANAGEMENT PROGRAMME
(ERMP)/ ENVIRONMENTAL IMPACT STATEMENT (EIS)**

(WA EPA Assessment Number 1240)

July 1999

Foreword

The Western Australian (WA) and Northern Territory (NT) Governments have agreed that the proposal to expand the Ord River Irrigation Scheme and develop the M2 Channel Supply Area should be jointly assessed using the WA environmental impact assessment process. It has also been agreed that the assessment should be as an Environmental Review and Management Programme (ERMP) (WA) and Environment Impact Statement (EIS) (NT).

Environment impact assessment is aimed at protecting the environmental by ensuring that development is environmentally sound and well managed. It also recognises that people want to have a say before the Governments make a decision.

Wesfarmers/ Marubeni and the Water Corporation of Western Australia, as co-proponents, have been required to prepare a joint ERMP and EIS to assist the WA Environmental Protection Authority (WA EPA) and NT Government in assessing the environmental impacts of the project. An environmental impact assessment is a document which describes to the WA and NT Governments, and the community what the proponents wants to do, what the environmental impacts will be and how the proponents intend to manage the project.

The WA Department of Environmental Protection (DEP), on behalf of the WA EPA, and the NT Department of Lands, Planning and Environment (DLPE), have jointly prepared guidelines for the ERMP/EIA. These guidelines identify environmental factors they expect the proponent to address in the ERMP/EIA.

Public comment was invited on the guidelines from 20 April 1999 to 14 May 1999. Comments received were taken into account in the final preparation of these guidelines.

Contents

Part A	Specific Guidelines for the preparation of the Environmental Review and Management Programme/ Environmental Impact Statement
Part B	Generic Guidelines for the preparation of an environmental review document

Attachment 1	Example of the invitation to make a submission
Attachment 2	Advertising the environmental review
Attachment 3	Project location map

These guidelines are provided for the preparation of the proponent's environmental review document. The specific environmental factors to be addressed are identified in Part A. The generic guidelines for the format of an environmental review document are provided in Part B.

The environmental review document must address all elements of Part 'A' and Part 'B' of these guidelines prior to approval being given to commence the public review.

Part A: Specific Guidelines for the preparation of the Environmental Review and Management Programme (ERMP)/ Environmental Impact Statement (EIS)

1. Introduction

Background

On 19 April 1995, the Premier of WA and the Chief Minister of the NT signed a Memorandum of Understanding regarding the expansion of the Ord River Irrigation Scheme.

The first part of the expansion of the scheme is the development of the M2 Channel Supply Area, which is located on the Weaber, Keep and Knox Creek Plains that straddle the WA/ NT border north of Kununurra (Attachment 3).

The proponents for the development of the M2 Channel Supply Area are Wesfarmers/ Marubeni and the Water Corporation of Western Australia as co-proponents, with the Wesfarmers/Marubeni joint venture responsible for development associated with the agricultural land and the Water Corporation responsible for water-related infrastructure.

The proposal

The proposal to develop the M2 Channel Supply Area involves the following major elements:

- development of approximately 36,000ha for farms and infrastructure, including ownership and operation by Wesfarmers/ Marubeni of approximately 27,000 ha of this land for sugarcane farms;
- development of a sugar mill by Wesfarmers/ Marubeni with a capacity of approximately 400,000 tpa of raw sugar and 160,000 tpa of molasses;
- development of raw sugar and molasses storage and handling facilities at Wyndham Port by Wesfarmers/ Marubeni;
- allocation of up to 15% of the net irrigable area for sale to independent farmers on an unconditional basis with respect to the types of crops that may be grown; and
- construction of approximately 400 km of water supply channels and drains, as well as almost 150 km of flood protection levees.

2. Assessment Context

The Ord Irrigation Area commenced agricultural land development in the 1960's. This proposal represents a second stage of irrigated land development, with water supplied from the existing Ord River Dam.

There has been substantial change in the context within which Stage 1 and Stage 2 need to be considered. For instance, the Stage 1 development preceded the WA *Environmental Protection Act 1986* and the related growth in community environmental awareness and statutory assessment. In addition, heritage legislation, water legislation reform, national and international biological diversity agreements and greenhouse gas protocols, and the national agreement on ecologically sustainable development have all been major additions to the broad context within

which this Stage 2 proposal must be examined. This context is not only important for proponents and relevant environmental agencies, but also for the community and the WA, NT and Commonwealth Governments.

A proposal of this scale also needs to be placed within a local and regional context, particularly for such factors as vegetation systems, land systems, water regimes, climate, and fauna. Consideration needs to be given to the adequacy of protection of environmental values within and adjoining the project area from the consequences of development.

The environmental impact assessment process requires the proponent of a proposed development to identify the environmental issues, to describe the environmental aspects of the development area and to outline how they intend to address environmental issues. Consideration also needs to be given to the proposed development area in a regional context. The determination of whether a particular proposed response is adequate is the role of the environmental assessor, through the assessment process, and the role of the associated Government in its decision-making. In order for those responses or solutions to be considered, there must be transparency by the proponent to show how those actions were chosen and the likely success of the selected response. The criteria used to define and select a particular response to an identified issue needs to be specified in the environmental documentation.

The WA EPA has decided that the assessment of this proposal will be undertaken in two stages. The first will look at the key environmental issues, of which the magnitude of the proposed clearing and its effect on biological diversity and significant social values are the major issues. The manner by which these and the other factors listed in these guidelines will be managed will form the second stage of the assessment. This approach means that there will be two assessment reports produced by the WA EPA.

To assist the proponent, community, the WA, NT and Commonwealth Governments, the WA EPA has outlined in these guidelines how it intends to approach the assessment of the implications for biological diversity.

The term 'environment' under the Northern Territory *Environmental Assessment Act 1982* means all aspects of the surroundings of man including the physical, biological, economic, cultural and social aspects. The term is more narrowly defined under the WA *Environmental Protection Act 1986*.

In view of this difference, some issues identified within these guidelines are beyond the scope of the WA EPA to consider in its assessment of the proposal and advice to the WA Minister for the Environment.

In preparing an ERMP/EIS, the proponent should bear in mind the following aims of the ERMP/EIS and public review process:

- to provide a source of information from which interested individuals and groups may gain an understanding of the proposal, the need for the proposal, the alternatives, the environment which it would affect, the impacts that may occur and the measures to be taken to minimise these impacts;
- to provide a forum for public consultation and informed comment on the proposal; and
- to provide a framework in which decision-makers may consider the environmental aspects of the proposal in parallel with economic, technical and other factors.

The proponent should ensure that the ERMP/EIS demonstrates compliance with the goals, objectives and guiding principles of Ecologically Sustainable Development as set out in the

National Strategy for Ecologically Sustainable Development and the principles set out in the National Strategy for the Conservation of Australia's Biological Diversity. The ERMP/EIS should describe the land in terms of its cultural, ecological, economic and social values.

As set out in the following guidelines, the scope of this assessment shall encompass those issues and alternatives directly related to the development of the Ord River Irrigation Area Stage 2 (M2 Channel Supply Area) project.

Social Impacts

A separate study of the social, cultural and economic impact of developments related to this project on Miriwung and Gajerrong people is being conducted by the Aboriginal Representative Bodies with the support of Wesfarmers/ Water Corporation in parallel to the ERMP/EIS.

To ensure that there is the opportunity for consideration by the public and assessors (WA EPA and NT DLPE) in a timely manner, information from this study and other reports should be referred to in the ERMP/EIS. Additional relevant information should be published prior to the assessors reporting to their respective Ministers.

A number of studies were commissioned by the Department of Resources Development (DRD) to consider social implications of a number of development scenarios for Ord Stage 2. These studies were carried out prior to the selection of Wesfarmers/ Marubeni and Water Corporation as the preferred developer for the M2 project area.

The ERMP/EIS is expected to update and revise information consistent with the specific development proposal.

Studies that contain social information that may be relevant to this assessment, include the:

- Kununurra-Wyndham Area Development Strategy (KWADS),
- Naralup Population Study;
- Beckwith Social Impact Assessments; and
- study by AACM International Pty Ltd titled 'Aboriginal Consultations - Ord River Irrigation Scheme Stage 2 (September 1997)'

(i) Kununurra-Wyndham Area Development Strategy (KWADS),

The KWADS study is being undertaken by the WA Ministry for Planning (MfP) in association with the Shire of Wyndham-East Kimberley and NT DLPE. The purpose of this study is to provide assistance to community, private enterprise and Government agencies to guide and control land use, protect and manage environmental and heritage values, recommend on settlement expansion, promote tourism/ development nodes, assess the need for further industrial land and coordinate transport and infrastructure provision.

This draft plan is expected to be released by the MfP for public review in the third quarter of 1999.

(ii) Naralup Populations Study

DRD commissioned this study in 1996 to examine the population impacts of developing Stage 2 of the irrigation project and identifies population categories generated by the development, tourism and other industry.

(iii) Beckwith Social Impact Assessments

Potential social impacts were examined by Dr Beckwith in 1997 as part of studies by Sinclair Knight Merz related to the Ord Stage 2 development. This study identified current community circumstances and the needs of the existing resident population and establishes what benefits and increased demands on social infrastructure may occur if the population were to substantially increase as a result of Stage 2.

(iv) Aboriginal Consultations - Ord River Irrigation Scheme Stage 2 (AACM)

DRD commissioned this study in 1997 to address Aboriginal aspects of social issues relating to the proposed development of the second phase of the Ord River Irrigation Area. The report complements the earlier social impact assessment conducted by Dr Beckwith.

The Naralup, Beckwith and AACM studies are available from DRD.

Water Allocation Plan

It is also important to note that the WA EPA will be providing advice to the WA Government on the Water and Rivers Commission Draft Interim Water Allocation Plan for the Ord River. This draft interim plan cannot be assessed by the WA EPA as it does not represent a proposal under the WA *Environmental Protection Act*. However, the WA EPA will provide advice in a report pursuant to S16(e) of the WA *Environmental Protection Act*.

The purpose of the interim plan is to:

- define bulk water allocations based on the available hydrological data and the estimates of demand for current and potential water uses;
- describe the system by which licences will be issued under current legislative arrangements; and
- describe the investigations required to allow allocations to be refined, and the process by which any review of allocations will be undertaken; and

The objectives of the interim plan are to:

- make an interim provision of water to the Lower Ord River system and its associated environment;
- determine the remaining water that may be available for diversion for consumptive uses;
- document interim allocation decisions as to how much water should be assigned to the Stage 1 and Stage 2 developments; and
- ensure those existing commitment and longer term demands for hydro-power generation can be accommodated within the interim allocations and that a feasible reservoir operating strategy can be developed that meets all commitments.

This draft interim plan has been released for public comment for a period of eight weeks, closing 20 August 1999.

3. Environmental factors relevant to this proposal

At this stage, the WA EPA believes the relevant environmental factors, objectives and work required is as detailed in the table below:

CONTENT		SCOPE OF WORK	
Factor	Site specific factor	WA EPA objective	Work required for the environmental review
BIOPHYSICAL			
Biodiversity	Ecosystems	To maintain biological diversity meaning the different plants and animals and the ecosystems they form, at the levels of genetic diversity, species diversity and ecosystem diversity.	Baseline studies to identify existing genetic diversity, species diversity and ecosystem diversity of the development area and in a relevant regional context to ensure that the project will not affect the diversity of and representativeness of biodiversity in the East Kimberley/ Western Northern Territory. Detail measures proposed to ensure: • avoidance of loss of biological diversity; • maintenance of ecological linkages between different ecosystems and habitat types; and. • protection or rehabilitation of representative ecosystems within and adjacent to the proposed irrigation scheme which have been identified as being of significant local and regional conservation value. Identify and define areas which are “comparable” to the project (including buffer areas) in terms of biodiversity and ecological function at the ecosystem, species and genetic levels. Assess the environmental significance of alterations to the species assemblages in terms of changes to ecosystem/ ecological function pre and post disturbance.

CONTENT		SCOPE OF WORK	
Factor	Site specific factor	WA EPA objective	Work required for the environmental review
Terrestrial flora	Vegetation communities	Maintain the species diversity, geographic distribution and productivity of vegetation communities.	Baseline studies to identify existing flora species and vegetation communities (including riparian) present in the proposal area and representation outside project area. Detail measures proposed: • to ensure protection or rehabilitation of representative vegetation communities within the local and regional context which have been identified as being of significant local and regional conservation value; • to ensure introduced crops and weeds are managed so that there are no adverse impacts on the adjacent terrestrial environment; • to address quarantine for disease; • for coordination of long term management of the proposed irrigation scheme to ensure no long term adverse impact on the conservation values of the adjacent terrestrial environment arise from the development; and • to establish buffer zones, protected areas and conservation zones to ensure the maintenance of dependant species.

	Declared Rare and Priority Flora	Protect Declared Rare and Priority Flora, consistent with the provisions of the WA Wildlife Conservation Act 1950 and other relevant State, Northern Territory and Commonwealth legislation.	Baseline studies to identify existing Declared Rare or Priority Flora (or equivalent under NT or Commonwealth legislation (including species listed on the schedules of the Commonwealth's <i>Endangered Species Protection Act 1992</i>) present in area of proposed development. Identify threats and potential threats to Declared Rare and Priority Flora (or equivalent under NT or Commonwealth legislation). Detail measures proposed to ensure protection or rehabilitation of any Declared Rare or Priority Flora (or equivalent under NT or Commonwealth legislation).

CONTENT		SCOPE OF WORK	
Factor	Site specific factor	WA EPA objective	Work required for the environmental review
Estuarine flora	Estuarine flora	Maintain the ecological function, abundance, species diversity and geographic distribution of estuarine and marine flora	Baseline studies to identify existing estuarine or marine vegetation assemblages of the Keep River and Sandy Creek. Detail measures proposed to ensure protection of marine flora downstream and in tidal reaches of Keep River and Sandy Creek from increased water flow, sediment load, pesticides and other chemical runoff.
Terrestrial fauna	Terrestrial fauna	Maintain the abundance, species diversity and geographical distribution of terrestrial fauna.	Baseline studies to identify existing occurrence of fauna and usage of the proposed development area by terrestrial fauna. Detail measures proposed to: • ensure protection or rehabilitation of fauna habitat, including that downstream of the proposed development; and • establish buffer zones, protected areas and conservation zones to ensure the existence of dependant species.

	Specially protected (threatened) fauna	Protect Specially Protected (Threatened) Fauna, consistent with the provisions of the WA Wildlife Conservation Act 1950 and other relevant State, Northern Territory and Commonwealth legislation. Protect Threatened Fauna and Priority Fauna species and their habitats, consistent with the provisions of the WA Wildlife Conservation Act 1950 and other relevant State, Northern Territory and Commonwealth legislation.	Baseline studies to identify existing usage of area of proposed development by Specially Protected (Threatened) or Threatened Fauna and Priority Fauna species (or equivalent under NT or Commonwealth legislation). This should include species protected by international agreements such as CAMBA, JAMBA and Ramsar and species listed on the schedules of the Commonwealth's <i>Endangered Species Protection Act 1992</i>. Detail measures proposed to ensure protection or rehabilitation of any Specially protected (threatened) or priority fauna species or habitat (or equivalent under NT or Commonwealth legislation). This should include species protected by international agreements such as CAMBA, JAMBA and Ramsar.

CONTENT		SCOPE OF WORK	
Factor	Site specific factor	WA EPA objective	Work required for the environmental review
	Subterranean fauna	Maintain the abundance, species diversity and geographical distribution of subterranean fauna	Baseline studies to identify existing usage of area of proposed development by subterranean fauna, including information on habitat use, ecological requirements, occurrence and tolerance of subterranean species to changes in water quality and level. Detail measures proposed to ensure protection or rehabilitation of any subterranean fauna habitat.
Aquatic fauna	Aquatic fauna	Maintain the ecological function, abundance, species diversity and geographic distribution of aquatic fauna.	Baseline studies to identify existing usage by aquatic fauna of rivers, streams and wetlands, including those downstream of proposed development. Detail measures to ensure aquatic fauna are not adversely affected by proposed development.
Wetlands	Wetlands	To protect the environmental values and maintain or enhance key ecological functions of the wetlands	Baseline studies to identify existing environmental values of permanent and seasonal wetlands within the project area and a description of their relative environmental and conservation significance. Identify wetlands within or in the vicinity of the project area that are listed as Wetlands of International Importance under the Ramsar Convention. Detail measures proposed to ensure protection, maintenance or enhancement of key environmental values of affected wetlands.
	Watercourses	Maintain the integrity, functions and environmental values of watercourses.	Baseline studies to identify existing environmental values of Keep River, Knox, Sandy and Border Creeks. Detail measures proposed to ensure protection and enhancement of environmental values of affected watercourses, including changes resulting from modifications to surface runoff and diversion of flows by the proposal.

	Groundwater quantity	Maintain groundwater so that existing and potential uses, including ecosystem maintenance are protected	Baseline studies to identify existing groundwater levels in the project area and existing components of the environment dependant on groundwater. Detail measures proposed to ensure protection of existing and potential uses, including ecosystem maintenance, from changes in groundwater levels.

CONTENT		SCOPE OF WORK	
Factor	Site specific factor	WA EPA objective	Work required for the environmental review
	Surface water quantity	Maintain surface water so that existing and potential uses, including ecosystem maintenance are protected	Baseline studies to determine surface water quantity and streamflows. Detail measures proposed to ensure no adverse downstream impacts arise from development.
	Mosquitoes and disease vectors	Mosquito numbers on-site should not adversely affect the health, welfare and amenity of future residents; and Ensure the breeding of mosquitoes is controlled to the satisfaction of the relevant public health agencies without adversely affecting other flora and fauna	Baseline studies to identify existing mosquito and other disease vectors present within or in the vicinity of the project area. Detail measures proposed to ensure disease vectors and pest, such as mosquitoes, are adequately monitored and managed. Where required provide details of drainage systems designed for the prevention of mosquito breeding. Note: the Kimberley region is within the receptive zone for malaria and Australian encephalitis is endemic.
Land	Hydrology	Establish stable, sustainable landform consistent with surroundings.	Baseline studies to document existing hydrological regimes across the project area, particularly in relation to watercourses, other landscape features and on the Weaber, Keep and Knox Plains. Detail measures proposed to: • avoid possible impacts from erosion, flooding and other changes resulting from modifications to surface runoff and groundwater behaviour; • ensure adjacent vegetation communities are unaffected by changes in natural sheet water flows or from altered surface water hydrology associated with diversion of water by the proposal; and • assess and respond to long term risks/trends in salinity and groundwater levels.

CONTENT		SCOPE OF WORK	
Factor	Site specific factor	WA EPA objective	Work required for the environmental review
POLLUTION MANAGEMENT			
Air	Particulates and dust	Ensure that the dust levels generated by the proposal do not adversely impact welfare and amenity of surrounding land users or cause health problems by meeting statutory requirements and acceptable standards.	Detail measures proposed to ensure impact from construction and operational activities comply with particulates and dust statutory requirements and guidelines.
	Chemical spray drift	Ensure that spray drift generated by chemicals used for the proposal does not adversely impact health, welfare and amenity of surrounding land users and the environment by meeting statutory requirements and acceptable standards.	Detail measures proposed to ensure impact from agricultural and other activities comply with statutory requirements and acceptable standards for chemical spray drift.
	Greenhouse gases	To minimise greenhouse gas emissions for the project and reduce emissions per unit product as low as reasonably practicable; and To mitigate greenhouse gases emissions in accordance with the Framework Convention on Climate Change 1992, and in accordance with established Commonwealth and State policies.	Baseline studies to estimate the existing greenhouse benefits related to the existing vegetation and land management practices within the project area. Detail measures proposed to ensure that greenhouse gas emissions meet acceptable standards and relevant State, NT and Commonwealth policy and legislation.

CONTENT		SCOPE OF WORK	
Factor	Site specific factor	WA EPA objective	Work required for the environmental review
Water	Groundwater quality	Maintain or improve the quality of groundwater to ensure that existing and potential uses, including ecosystem maintenance are protected.	Baseline studies to identify existing groundwater quality in the superficial and related deep aquifers within and in the vicinity of the project area. Detail measures proposed to: - ensure existing and potential groundwater uses, including ecosystem maintenance are protected; and - ensure that potential for pollution (as a result of the application of herbicides, pesticides and fertilisers) and salinity is managed so that there are no adverse impacts on groundwater quality.
	Surface water quality	Maintain or improve the quality of surface water to ensure that existing and potential uses, including ecosystem maintenance are protected.	Baseline studies to identify existing surface water quality in watercourses and other surface flows in the project area. Assessment of the potential presence and potential impacts from acid sulphate soils. Detail measures proposed to: - ensure the quality of surface water is maintained so that existing and potential uses, including ecosystem maintenance are protected; and - ensure that potential for pollution (as a result of increased sediment loads, herbicides, pesticides and fertilisers) and salinity is managed so that there are no adverse impacts on surface water quality.
SOCIAL SURROUNDINGS			
Recreation	Recreation	Maintain or enhance recreational usage of the project area, consistent with plans developed by planning agencies.	Baseline studies to identify existing recreational uses within and in the vicinity of the project area. Detail measures to maintain recreational values within the project area, especially the Keep River.

CONTENT		SCOPE OF WORK	
Factor	Site specific factor	WA EPA objective	Work required for the environmental review
Culture and heritage	Aboriginal heritage and culture	Ensure the proposal complies with the requirements of relevant State, Northern Territory and Commonwealth legislation; and Ensure that changes to the biological and physical environment resulting from the project do not adversely affect cultural associations with the area.	Describe the archaeological and heritage values of the project area and their relationship to other relevant areas. Describe the cultural and traditional relationship of Miriuwung and Gajerrong people with the environment of the project area. Describe the Native Title rights and interests of Aboriginal people in relation to the project area as they are affected by the proposal. Detail measures proposed to: • ensure the proposal complies with the <i>Aboriginal Heritage Act</i> and other relevant State, NT and Commonwealth legislation including the <i>Australian Heritage Commission Act 1975</i>; • ensure that changes to the biological and physical environment do not adversely affect cultural and traditional associations and the use of the area; • address rights and interests of Aboriginal people that may be affected by changes to the biological and physical environment; and • ensure appropriate consultation with traditional owners and the community.
Social	Social surrounds	To maintain and protect the aesthetic, cultural, economic and social surroundings, where those surroundings affect or are affected by physical or biological change.	Describe the existing and anticipated demographics in the project area and in other areas affected by the proposal (eg Kununurra and Wyndham). Describe community infrastructure requirements resulting from the proposal, including in Kununurra and Wyndham. Describe the existing wilderness and aesthetic values of the project area. Detail measures to maintain and protect wilderness and aesthetic values.

OTHER			
Cumulative impact			Describe relationships between this proposal and other land uses (eg Ord Stage 1). Detail measures proposed to ensure that cumulative environmental impacts are avoided and/or managed.

These factors should be addressed within the environmental review document for the public to consider and make comment to the WA EPA. The WA EPA expects to address these factors in its report to the Minister for the Environment. The factor of biological diversity is discussed in more detail in Section 4 of these guidelines.

The WA EPA expects the proponent to take due care in ensuring any other relevant environmental factors which may be of interest to the public are addressed.

4. The environmental factor of biological diversity

The Ord River Stage 2 M2 proposal involves substantial development of up to 50,000 ha of land on the Weaber Plain, Knox River Plain and Keep River Plain, located within the Kimberley region of WA and the adjoining portion of the NT. There will be large-scale clearing of land within pastoral lease, for irrigated agriculture and related infrastructure, new water-related management requirements, as well as issues associated with the introduction of agricultural crops and chemicals. These developments will require a significant change in the environment in both the short-term and longer-term.

Environmental impact assessment of the proposal will require the consideration of these short and long-term issues and their individual and cumulative consequences. For instance, the loss of up to 50,000 ha of vegetation through clearing is one of the fundamental environmental issues, both from the point of view of the extent of clearing as well as the threats to biological diversity in doing so.

This consideration relates to the environmental factor of biological diversity, which must be addressed through the proposal approval process. In WA this will require approvals in at least three areas: environmental approval under the WA *Environmental Protection Act* 1986, water provision under the WA *Rights in Water and Irrigation Act* 1911, and government approval through a new State Agreement Act. The latter two cannot proceed until environmental approval has been obtained.

The WA EPA has given consideration to how it will assess this key environmental factor of biological diversity.

In 1996 the Commonwealth Government, with all State and Territory Governments, signed the National Strategy for the Conservation of Australia's Biological Diversity. Conservation of biological diversity is a foundation of ecologically sustainable development. In this regard, one of the objectives of the National Strategy for Ecologically Sustainable Development is to protect biological diversity at the ecosystem, species and genetic levels and to maintain essential ecological processes and life-support systems.

The National Strategy for the Conservation of Australia's Biological Diversity adopted the following principles as a basis for the Strategy's objectives and actions. These should be used as a guide for implementation:

1. Biological diversity is best conserved in-situ.
2. Although all levels of government have clear responsibility, the cooperation of conservation groups, resource users, indigenous peoples, and the community in general is critical to the conservation of biological diversity.
3. It is vital to anticipate, prevent and attack at source the causes of significant reduction or loss of biological diversity.
4. Processes for and decisions about the allocation and use of Australia's resources should be efficient, equitable and transparent.
5. Lack of full knowledge should not be an excuse for postponing action to conserve biological diversity.
6. The conservation of Australia's biological diversity is affected by international activities and requires actions extending beyond Australia's national jurisdiction.
7. Australians operating beyond our national jurisdiction should respect the principles of conservation and ecologically sustainable use of biological diversity and act in accordance with any relevant national or international laws.
8. Central to the conservation of Australia's biological diversity is the establishment of a comprehensive, representative and adequate system of ecologically viable protected areas integrated with the sympathetic management of all other areas, including agricultural and other resource production systems.
9. The close, traditional association of Australia's indigenous peoples with components of biological diversity should be recognised, as should the desirability of sharing equitably benefits arising from the innovative use of traditional knowledge of biological diversity.

In its consideration of the consequences of the proposal on biological diversity, the WA EPA will focus on these principles and the related objectives and actions in the National Strategy. The WA EPA would expect that the WA, NT and Commonwealth Governments will take account of these principles prior to making any decisions in relation to the proposal, and the WA EPA will ensure that the proponent has addressed these principles in the ERMP. In addition, it is clear to the WA EPA that, in view of the scale of the proposal, the proponent alone may not be able to protect biological diversity and that it will require the participation of the WA and NT Governments as well.

The WA EPA's consideration of biological diversity will include the following basic elements:

- a comparison of a number of development scenarios to evaluate protection of biodiversity at the species and ecosystem levels;
- no known species of plant or animal is caused to become extinct as a consequence of the development and the risks to threatened species are considered to be acceptable;
- no association or community of indigenous plants ceases to exist as a result of the project;
- there is comprehensive, adequate and secure representation of scarce or endangered habitats within the project area and/or in areas which are biologically comparable to the project area within WA and the NT, protected in secure reserves;

- the project area itself includes a comprehensive and adequate network of conservation areas and linking corridors whose integrity and biodiversity is secure and protected; and
- the on-site and off-site impacts of the project are identified and the proponent demonstrates that these impacts can be managed.

In relation to land clearing, the WA EPA notes that Objective 7.1 of the National Strategy commits State, Territory and Commonwealth Governments by the year 2000 to, among other things:

- “ (l) *arresting and reversing the decline of remnant native vegetation; and*
- (m) *avoiding or limiting any further broad-scale clearance of native vegetation, consistent with ecologically sustainable management and bioregional planning, to those instances in which regional biological diversity objectives are not compromised.*” (Commonwealth of Australia 1996, p.42)

5. Availability of the environmental review

5.1 Copies for distribution free of charge

Supplied to DEP:

- Library/Information Centre..... 9
- WA EPA members..... 6
- Officers of the DEP (Perth) 8

Distributed by the proponent to:

Government Departments:

- Aboriginal Affairs Department..... 1
- Agriculture Western Australia..... 2
- Department of Conservation and
Land Management 2
- Department of Land Administration..... 1
- Department of Minerals and Energy 1
- Department of Resources
Development..... 2
- Environment Australia 10
- Fisheries Western Australia..... 2
- Kimberley Development Commission 2
- Main Roads Western Australia..... 1
- Northern Territory Department of
Lands Planning and Environment 10
- [and 2 copies on CD rom in ADOBE format (*.pdf)]
- Water and Rivers Commission..... 2
- Western Australian Museum 2

Local government authorities:

- Shire of Wyndham/ East Kimberley 2

Libraries:

- J S Battye Library 3
- The Environment Centre (WA)..... 2
- The Environment Centre (NT)..... 3
- Shire of Wyndham/ East Kimberley Library 2 (each at least)

Other:

- Aboriginal Legal Service 2
- Conservation Council of WA..... 1
- Kimberley Land Council..... 2
- Northern Land Council 2
- Waringarri Aboriginal Corporation 1

5.2 Available for public viewing

- J S Battye Library (WA)
- Shire of Wyndham/ East Kimberley Libraries
- Department of Environmental Protection Library
- NT Department of Lands Planning and Environment
- Department Lands Planning and Environment in Katherine
- NT State Library
- NT Parks and Wildlife Commission at Timber Creek
- Waringarri (Kununurra)
- Joorook Ngari (Wyndham)

Part B: Generic Guidelines for the preparation of an environmental review document

1. Overview

All environmental reviews have the objective of protecting the environment. Environmental impact assessment is deliberately a public process in order to obtain broad ranging advice. The review requires the proponent to describe:

- the proposal;
- receiving environment;
- potential impacts of the proposal on factors of the environment; and
- proposed management strategies to ensure those environmental factors are appropriately protected.

Throughout the assessment process it is the objective of the WA EPA to help the proponent to improve the proposal so the environment is protected. The DEP will co-ordinate, on behalf of the WA EPA, relevant government agencies and the public in providing advice about environmental matters during the assessment of the environmental review for this proposal.

The primary purpose of the environmental review is to provide information on the proposal within the local and regional framework to the WA EPA, with the aim of emphasising how the proposal may impact the relevant environmental factors and how those impacts may be mitigated and managed.

The language used in the body of the environmental review should be kept simple and concise, considering the audience includes non-technical people, and any extensive, technical detail should either be referenced or appended to the environmental review. It should be noted that the environmental review will form the legal basis of the Minister for the Environment's approval of the proposal and therefore the environmental review should include a description of all the main and ancillary components of the proposal, including options where relevant.

Information used to reach conclusions should be properly referenced, including personal communications. Such information should not be misleading or presented in a way that could be construed to mislead readers. Assessments of the significance of an impact should be soundly based rather than unsubstantiated opinion, and each assessment should lead to a discussion of the management of the environmental factor.

For the purposes of assessment, the project officer should be supplied with an electronic copy of the document for use on Macintosh, Microsoft Word Version 6, and any scanned figures. Where possible, figures should be reproducible in a black and white format.

2. Objectives of the environmental review

The objectives of the environmental review are to:

- place this proposal in the context of the local and regional environment;
- adequately describe all components of the proposal, so that the Minister for the Environment can consider approval of a well-defined project;

- provide the basis of the proponent's environmental management program, which shows that the environmental impacts resulting from the proposal, including cumulative impact, can be acceptably managed; and
- communicate clearly with the public (including government agencies), using written material, video or other means, so that the WA EPA can obtain informed public comment to assist in providing advice to government.

3. Environmental management

The WA EPA expects the proponent to have in place an environmental management system appropriate to the scale and impacts of the proposal including provisions for performance review and a commitment to continuous improvement. The system may be integrated with quality and health and safety systems and should include the following elements:

- environmental policy and commitment;
- planning of environmental requirements;
- implementation and operation of environmental requirements;
- measurement and evaluation of environmental performance; and
- review and improvement of environmental outcomes.

A description of the proposed environmental management system should be included in the environmental review documentation. If appropriate, the documentation can be incorporated into a formal environmental management system (such as AS/NZS ISO 14001). Public accountability should be incorporated into the approach on environmental management.

The environmental management program (EMP) is the key document of an environmental management system that should be adequately defined in an environmental review document. The EMP should provide plans to manage the relevant environmental factors, define the performance objectives, describe the resources to be used, outline the operational procedures and outline the monitoring and reporting procedures which would demonstrate the achievement of the objectives.

4. Format of the environmental review document

The environmental review should be provided to the DEP officer for comment. At this stage the document should have all figures produced in the final format and colours.

Following approval to release the review for public comment, the final document should also be provided to the DEP in an electronic format.

The proponent is requested to supply the project officer with an electronic copy of the environmental review document for use on Macintosh, Microsoft Word Version 6, and any scanned figures. Where possible, figures should be reproducible in a black and white format.

5. Contents of the environmental review document

The contents of the environmental review should include an executive summary, introduction and at least the following:

5.1 The proposal

A comprehensive description of the proposal including its location (address and certificate of title details where relevant) is required.

Justification and alternatives

- justification and objectives for the proposed development;
- the legal framework, including existing zoning and environmental approvals, and decision making authorities and involved agencies; and
- consideration of alternative options (including a ‘no development’ option).

Key characteristics

The Minister’s statement will bind the proponent to implementing the proposal in accordance with any technical specifications and key characteristics¹ in the environmental review document. It is important therefore, that the level of technical detail in the environmental review, while sufficient for environmental assessment, does not bind the proponent in areas where the project is likely to change in ways that have no environmental significance.

Include a description of the components of the proposal, including the nature and extent of works proposed. This information must be summarised in the form of a table as follows:

¹ Changes to the key characteristics of the proposal following final approval, would require assessment of the change and can be treated as non-substantial and approved by the Minister, if the environmental impacts are not significant. If the change is significant, it would require assessment under section 38 or section 46. Changes to other aspects of the proposal are generally inconsequential and can be implemented without further assessment. It is prudent to consult with the Department of Environmental Protection about changes to the proposal.

Table 1: Key characteristics (example only)

Element	Description
Life of project (mine production)	< 5yrs (continual operation)
Size of ore body	682 000 tonnes (upper limit)
Area of disturbance (including access)	100 hectares
List of major components • pit • waste dump • infrastructure (water supply, roads, etc)	Refer plans, specifications, charts section immediately below for details of map requirements
Ore mining rate • maximum	• 200 000 tonnes per year
Solid waste materials • maximum	• 800,000 tonnes per year
Water supply • source • maximum hourly requirement • maximum annual requirement	• XYZ borefield, ABC aquifer • 180 cubic metres • 1 000 000 cubic metres
Fuel storage capacity and quantity used	Litres; litres per year
Heavy mineral concentrate transport • truck movements (maximum)	• 75 return truck loads per week

Plans, Specifications, Charts

Adequately dimensioned plans showing clearly the location and elements of the proposal which are significant from the point of view of environmental protection, should be included. The location and dimensions (for progressive stages of development, if relevant) of plant, amenities buildings, accessways, stockpile areas, dredge areas, waste product disposal and treatment areas, all dams and water storage areas, mining areas, storage areas including fuel storage, landscaped areas etc.

Only those elements of plans, specifications and charts that are significant from the point of view of environmental protection are of relevance here.

Figures that should always be included are:

- a map showing the proposal in the local context - an overlay of the proposal on a base map of the main environmental constraints;
- a map showing the proposal in the regional context; and, if appropriate
- a process chart / mass balance diagram showing inputs, outputs and waste streams.

The plan/s should include contours, a north arrow, a scale bar, a legend, grid co-ordinates, the source of the data, and a title. If the data is overlaid on an aerial photo then the date of the aerial photo should be shown.

Other logistics

- timing and staging of project; and
- ownership and liability for waste during transport, disposal operations and long-term disposal (where appropriate to the proposal).

5.2 Environmental factors

The environmental review should focus on the relevant environmental factors for the proposal, and these should be agreed in consultation with the WA EPA and DEP and relevant public and government agencies. Preliminary environmental factors identified for the proposal are shown in Part A of these guidelines.

Further environmental factors may be identified during the preparation of the environmental review, therefore on-going consultation with the WA EPA, DEP and other relevant agencies is recommended. The DEP can advise the proponent on the recommended WA EPA objective for any new environmental factors raised. Minor matters which can be readily managed as part of normal operations for the existing operations or similar projects may be briefly described.

Items that should be discussed under each environmental factor are:

- a clear definition of the area of assessment for this factor;
- the WA EPA objective for this factor;
- a description of what is being affected - why this factor is relevant to the proposal;
- a description of how this factor is being affected by the proposal - the predicted extent of impact;
- a description of where this factor fits into the broader environmental / ecological context (only if relevant - this may not be applicable to all factors);
- a straightforward description or explanation of any relevant standards / regulations / policy;
- environmental evaluation - does the proposal meet the WA EPA's objective as defined above;
- if not, environmental management proposed to ensure the WA EPA's objective is met; and
- predicted outcome.

The proponent should provide a summary table of the above information for all environmental factors, under the three categories of biophysical, pollution management and social surroundings:

Table 2: Environmental factors and management (example only)

Environmental Factor	WA EPA Objective	Existing environment	Potential impact	Environmental management	Predicted outcome
BIOPHYSICAL					
Vegetation community types 3b and 20b	Maintain the abundance, species diversity, geographic distribution and productivity of vegetation community types 3b and 20b	Reserve 34587 contains 45 ha of community type 20b and 34 ha of community type 3b	Proposal avoids all areas of community types 20b and 3b	Surrounding area will be fully rehabilitated following construction	Community types 20b and 3b will remain untouched Area surrounding will be revegetated with seed stock of 20b and 3b community types
POLLUTION MANAGEMENT					
Dust	Ensure that the dust levels generated by the proposal do not adversely impact upon welfare and amenity or cause health problems by meeting statutory requirements and acceptable standards	Light industrial area - three other dust producing industries in close vicinity Nearest residential area is 800 metres	Proposal may generate dust on two days of each working week.	Dust Control Plan will be implemented	Dust can be managed to meet WA EPA's objective
SOCIAL SURROUNDINGS					
Visual amenity	Visual amenity of the area adjacent to the project should not be unduly affected by the proposal	Area already built-up	This proposal will contribute negligibly to the overall visual amenity of the area	Main building will be in 'forest colours' and screening trees will be planted on road	Proposal will blend well with existing visual amenity and the WA EPA's objective can be met

5.3 Environmental management commitments

The implementation of the key characteristics of the proposal and the environmental management commitments made by the proponent become legally enforceable under the conditions of environmental approval issued in the statement by the Minister for the Environment. All the auditable environmental management commitments should be consolidated in the public review document in a list (usually in an Appendix). This list is attached to the Minister's statement and becomes part of the conditions of approval.

The proponent's compliance with the consolidated environmental management commitments will be audited by the DEP, so they must be expressed in a way which enables them to be audited.

A commitment needs to contain most (if not all) of the following elements to be auditable:

- who (eg. the proponent)

- will do what (eg. prepare a plan, take action)
- why (to meet an environmental objective)
- where/how (detail the action and where it applies)
- when (in which phase, eg. before construction starts)
- to what standard (recognised standard or agency to be satisfied)
- on advice from (agency to be consulted).

The proponent may make other ‘commitments’, which address less significant or non-environmental matters, to show an intention to good general management of the project. Such ‘commitments’ (or management strategies/policies) would not be included in the consolidated list of environmental management commitments appended to the statement.

Continuous improvement during the implementation of the consolidated commitments may necessitate changes whilst ensuring the environmental objective is still achieved; these can be made in updates to the environmental management plan. Modified and/or additional proponent commitments arising from the fulfilment of environmental conditions will be audited by the DEP and should follow the accepted format.

Once the proposal is approved under a statement of conditions, any proposed modifications or additional commitments should be referred to the WA EPA for consideration of the environmental impacts. Such changes to the consolidated list of commitments would normally be dealt with through the audit process; however, if significant impacts are involved, the proposed changes may constitute a change to the proposal which would require assessment.

Examples of the preferred format for typical commitments are shown in the following table:

Table 3: Summary of proponent’s commitments (example only)

Who/What <u>Commitment</u>	When plan prepared <u>Timing</u>	Why <u>Objective</u>	How/Where <u>Action</u>	Whose advice <u>expert consulted</u>	Evidence Standard Compliance criteria
1. The Proponent will develop and implement a rehabilitation plan	before construction commences	to protect the abundance, species diversity, geographic distribution and productivity of the vegetation community types 3b and 20b (fig 3.1, EMP)	by limiting construction to 10 ha of Reserve 34587 and rehabilitating the area	on advice of CALM.	similarity rating of rehab’d area consistent with vegetation community types 3b and 20b.
2. The Proponent will prepare and implement a dust control plan	before the start of construction	to minimise dust generation and impact on nearby land owners	by measures such as watering roads and monitoring wind direction	preparation of the plan on advice of DEP.	1000mg/m3 (WA EPA Dust Control Criteria)

Commitments should preferably be written in tabular format, preferably with some specification of ways in which the commitment can be measured, or how compliance can be demonstrated.

Draft commitments, whether in textual or tabular format, which are not in a format that can be audited will not be accepted by DEP assessment officers for public review documentation. Proponents will be assisted to revise inadequate commitments.

5.4 Public consultation

A description should be provided of the public participation and consultation activities undertaken by the proponent in preparing the environmental review. It should describe the activities undertaken, the dates, the groups/individuals involved and the objectives of the activities. Cross reference should be made with the description of environmental management of the factors which should clearly indicate how community concerns have been addressed. Those concerns which are dealt with outside the WA EPA process can be noted and referenced.

5.5 Other information

Additional detail and description of the proposal, if provided, should go in a separate section.

Attachment 1

The first page of the proponent's environmental review document must be the following invitation to make a submission, with the parts in square brackets amended to apply to each specific proposal. Its purpose is to explain what submissions are used for and to detail why and how to make a submission.

Invitation to make a submission

The Environmental Protection Authority (WA EPA) invites people to make a submission on this proposal.

[the proponent] proposes [the rezoning of land and the development of a Marina Complex in the City of Bunbury]. In accordance with the WA *Environmental Protection Act*, a [PER] has been prepared which describes this proposal and its likely effects on the environment. The [PER] is available for a public review period of [8] weeks from [date] closing on [date].

Comments from government agencies and from the public will help the WA EPA to prepare an assessment report in which it will make recommendations to government.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the WA EPA will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the Freedom of Information Act, and may be quoted in full or in part in the WA EPA's report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining with a group interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the [PER] or the specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal more environmentally acceptable.

When making comments on specific elements of the [PER]:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable;
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- attempt to list points so that issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the [PER];
- if you discuss different sections of the [PER], keep them distinct and separate, so there is no confusion as to which section you are considering; and
- attach any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name;
- address;
- date; and
- whether you want your submission to be confidential.

The closing date for submissions is: **[date]**

Submissions should be addressed to:

The Environmental Protection Authority
Westralia Square
141 St George's Terrace
PERTH WA 6000

Attention: Juliet Cole

Attachment 2

Advertising the environmental review

The proponent is responsible for advertising the release and arranging the availability of the environmental review document in accordance with the following guidelines:

Format and content

The format and content of the advertisement should be approved by the DEP before appearing in the media. For joint State-Commonwealth assessments, the Commonwealth also has to approve the advertisement. The advertisement should be consistent with the attached example.

Note that the DEP officer's name should appear in the advertisement.

Size

The size of the advertisement should be two newspaper columns (about 10 cm) wide by about 14 cm long. Dimensions less than these would be difficult to read.

Location

The approved advertisement should, for CER's, appear in the news section of the main local newspaper and, for PER's and ERMP's, appear in the news section of the main daily paper's ("The West Australian") Saturday edition, and in the news section of the main local paper at the commencement of the public review period and again two weeks prior to the closure of the public review period.

Timing

Within the guidelines already given, it is the proponent's prerogative to set the time of release, although the DEP should be informed. The advertisement should not go out before the report is actually available, or the review period may need to be extended.

Example of the newspaper advertisement

SCM CHEMICALS LTD
Consultative Environmental Review
EXTENSION TO DALYELLUP RESIDUE DISPOSAL PROGRAM
(Public Review Period: **[date]** to **[date]**)

SCM Chemicals Ltd is planning to extend the company's existing residue disposal program at Dalyellup, south of Bunbury, from March 1992 to March 1993.

A Consultative Environmental Review (CER) has been prepared by the company to examine the environmental effects associated with the proposed development, in accordance with Western Australian Government procedures. The CER describes the proposal, examines the likely environmental effects and the proposed environmental management procedures.

SCM has prepared a project summary which is available free of charge from the company's office on Old Coast Road, Australind.

Copies of the CER may be purchased for \$5 from:

SCM Chemicals Ltd
Old Coast Road
AUSTRALIND WA 6230
Telephone: (08) 9467 2356

Copies of the complete Consultative Environmental Review will be available for examination at:

- Environmental Protection Authority
Library Information Centre
8th Floor, Westralia Square
38 Mounts Bay Road
PERTH WA 6000
- City of Bunbury public libraries
- Shire of Capel libraries
- Shire of Harvey library (Australind)
- Environmental Protection Authority
65 Wittenoom Street
BUNBURY WA 6230
- Shire of Dardanup (Eaton)

Submissions on this proposal are invited by **[closing date]**. Please address your submission to:

Chairman
Environmental Protection Authority
8th Floor, Westralia Square
141 St Georges Terrace
PERTH WA 6000
Attention: **[Juliet Cole]**

If you have any questions on how to make a submission, please ring the project officer, **[Project Officer name]**, on (08) 9222 7xxx.

APPENDIX B

GLOSSARY

APPENDIX B

GLOSSARY

Accessions	Water infiltration from the ground surface to underlying aquifers.
Adsorption	The concentration or sorption of one substance on the surface of another.
Aeolian	Descriptive of soil deposited by wind.
Aquifer	A permeable rock formation that stores and transmits sufficient groundwater to yield significant quantities of water to wells, bores or springs.
Arboreal	Of living in, or connected with trees.
Avian	Of, or relating to birds.
Avifauna	Birds of a region or country collectively.
Bagasse	The fibrous residue left after the extraction of juice from sugarcane.
Biogeographic region	A territory defined by a combination of biological, social and geographic criteria rather than by geopolitical considerations; generally, a system of related, interconnected ecosystems.
Biological diversity	The variety of life forms: the different plants, animals and microorganisms, the genes they contain, and the ecosystems they form.
Calcareous	Composed of, or containing calcium compounds, particularly calcium carbonate.
Calcrete	Friable to hard calcareous material of secondary accumulation found near or on the surface, and composed largely of crusts of soluble calcium salts intermixed with gravel, sand, salt and clay.
Carbon dioxide equivalent carbon	The amount of carbon that would need to be fully combusted to produce carbon dioxide with an equivalent global warming potential.
Colloid	A mixture of ultramicroscopic (i.e. clay) particles in water.
Conservation	The protection, maintenance, management, sustainable use, restoration and enhancement of the natural environment.
Cucurbits	Gourds (e.g. melons and pumpkins).
Cuesta	A gentle slope, especially one ending in a steep drop.
Enzootic	Regularly affecting animals in a particular district or at a particular season.
Evapotranspiration	The return of water vapour to the atmosphere by evaporation from land and water surfaces and by the transpiration of vegetation.
Feral species	A domesticated species that has become wild.
Fluvial	Of, or found in, a river or rivers.
Gilgai	The microrelief of soils produced by expansion and contraction with changes in moisture, found in soils that contain large amounts of clay. It is characterised by a markedly undulating surface with mounds and depressions.
Global warming	The increase in temperature of the earth's atmosphere caused by the greenhouse effect.
Global warming potential	The potential for a gas to contribute to global warming. Usually expressed as a factor of carbon dioxide. Factors are published by the Intergovernmental Panel on Climate Change.
Greenhouse gas	Any of the various gases, especially carbon dioxide, that contribute to the greenhouse effect.
Greenhouse sinks	Activities that sequester greenhouse gases from the atmosphere.
Habitat	The place or type of site in which an organism naturally occurs.

Hogback	A steep-sided ridge of a hill.
Hydrogeology	The science dealing with groundwater and with related geological aspects of surface water.
Indicator species	A species whose presence or absence is indicative of a particular habitat, community or set of environmental conditions.
Karstic	Descriptive of uneven limestone topography, characterised by depressions, fissures, etc., created by percolating waters.
Metabolite	A substance produced during, or taking part in, metabolism.
Native vegetation	Any local indigenous plant community containing throughout its growth the complement of native species and habitats normally associated with that vegetation type or having the potential to develop these characteristics.
Organochlorine	A compound containing carbon and chlorine.
Organophosphate	A compound containing carbon and phosphorous.
Palaeochannel	Buried channel of a watercourse from the geological past.
Pediment	A broad flattish rock surface at the foot of a mountain slope.
Riparian	Of or on a riverbank.
Saxicoline	Rock inhabiting.
Smut	A group of Basidiomycete fungi (order Ustilaginales) with sooty spore masses.
Sodicity	A form of land degradation involving sodic soils (clay particles with attached sodium ions), resulting in poor water infiltration, surface crusting, erosion and water logging.
Solodic	Soils with strong differences in texture with increasing depth; acid surface layers and strongly alkaline deeper layers.
Species	A group of organisms capable of interbreeding freely with each other but not with members of other species.
Stygofauna	Fauna (usually invertebrae) that live exclusively in subterranean habitats.
Synclinal	Rock formation having the characteristics of a trough.
Tailwater	Irrigation water that leaves the end of the furrow.
Taxon (pl. taxa)	The named classification unit to which individuals or sets of species are assigned, such as species, genus and order.
Threatened	A species or community that is vulnerable or endangered.
Transgenic	Having genetic material introduced from another species of animal or plant.
Trash	The refuse of stripped leaves and tops produced during the harvesting of sugarcane.
Vector	Any organism that conveys a disease-producing organism from one host to another, either within or on the surface of its body.
Volatilisation	Vaporization, evaporation.
Wilderness	Land that, together with its plant and animal communities, is in a state that has not been substantially modified by, and is remote from, the influences of European settlement or is capable of being restored to such a state, and is of sufficient size to make its maintenance in such a state feasible.

APPENDIX C

ABBREVIATIONS

APPENDIX C

ABBREVIATIONS

Measurements

Technical units of measurement in this report are based on the International System of Units (SI) wherever possible. These technical units may be broadly grouped as prefixes and measurements. A prefix applies to the unit of measurement that immediately follows it—for example, milligram is abbreviated as mg. Superscripts ² and ³ following a linear unit indicate area and volume respectively—for example, m² (square metres) and m³ (cubic metres). Different units are combined by a full stop (.) to differentiate units of the same exponential sign, and a solidus (/) to indicate ‘per’. For example, kilometres per hour is abbreviated as km/h, while megalitres per day per square kilometre is ML/d.km².

Prefixes

G	giga	1,000,000,000
M	mega	1,000,000
k	kilo	1,000
m	milli	0.001
μ	micro	0.000001
n	nano	0.000000001

Units of Measurement

a	year (annum)
BP	before present
cm	centimetre(s)
EC _e	electrical conductivity of saturation extract
g	grams(s)
GL	gigalitre(s)
GL/a	gigalitre(s) per year
g/m ³	grams(s) per cubic metre
g/Nm ³	gram(s) per normal cubic metre(s) (gas volume at 0°C and 1 atmosphere)
ha	hectare(s)
ha/a	hectare(s) per year
kg	kilogram(s)
kg/h	kilogram(s) per hour
kg/ha	kilogram(s) per hectare
kg/m ³	kilogram(s) per cubic metre
km	kilometre(s)
km ²	square kilometre(s)
km/h	kilometre(s) per hour

L	litre(s)
lb	pound(s)
L/s	litre(s) per second
m	metre(s)
m ³ /h	cubic metre(s) per hour
mg/L	milligram(s) per litre
ML	megalitre(s)
ML/a	megalitre(s) per year
ML/d	megalitre(s) per day
ML/ha	megalitre(s) per hectare
mm	millimetre(s)
mm/a	millimetre(s) per year
mm/d	millimetre(s) per day
mm/h	millimetre(s) per hour
m ³ /s	cubic metre(s) per second
m/s	metre(s) per second
Mt	megatonne(s)
Mt/a	megatonne(s) per annum
MW	megawatt(s)
NTU	Nephelometric turbidity unit
pH	degree of alkalinity/acidity
p.p.m.	parts per million
s	second(s)
t	tonne(s)
t/a	tonne(s) per year
t/d	tonne(s) per day
t/h	tonne(s) per hour
µg/L	microgram(s) per litre
µSv/cm	microsievert(s) per centimetre
USc/lb	cents (United States of America) per pound weight
\$	dollar(s)
°C	degree(s) Celsius
%	per cent

General

AAD	Aboriginal Affairs Department
AAPA	Aboriginal Areas Protection Authority
ACMC	Aboriginal Cultural Material Committee
AGWEST	Agriculture Western Australia

AHA	<i>Aboriginal Heritage Act 1972</i>
AHC	Australian Heritage Commission
AHCA	<i>Australia Heritage Commission Act 1975</i>
AHD	Australian Height Datum
ALRA	<i>Aboriginal Land Rights (Northern Territory) Act 1976</i>
ALS	Aboriginal Legal Service
ANCA	Australian Nature Conservation Agency
ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average Recurrence Interval
ASEIA	Aboriginal Socio-Economic Impact Assessment
ASSANTA	<i>Northern Territory Aboriginal Sacred Sites Act 1989</i>
ATSIHPA	<i>Aboriginal and Torres Strait Islander Heritage Protection Act 1984</i>
BOD	Biological oxygen demand
CALM	Department of Conservation and Land Management
CAMBA	China–Australia Migratory Birds Agreement
CDEP	Community Development Employment Projects
CHMP	Cultural Heritage Management Plan
COAG	Council of Australian Governments
Co-proponents	Wesfarmers Sugar Company Pty Ltd, Marubeni Corporation and the Water Corporation of Western Australia
CRES	Centre for Resource and Environmental Studies
DAP	Diammonium phosphate
DEP	Department of Environmental Protection
DOLA	Department of Land Administration
DPIF	Department of Primary Industry and Fisheries
DRD	Department of Resources Development
EIS	Environmental Impact Statement
EKAMS	East Kimberley Aboriginal Medical Service
EMP	Environmental Management Plan
EPA	Environmental Protection Authority (Western Australia)
ERMP	Environmental Review and Management Programme
ESD	Ecologically Sustainable Development
ESP	Exchangeable sodium percentage
Fisheries	Fisheries Western Australia
FOB	Free on Board
HAC	Heritage Advisory Council
HCA	<i>Heritage Conservation Act 1991</i>
HCB	Heritage Conservation Branch

HCWA	Heritage Council of Western Australia
HWAA	<i>Heritage of Western Australia Act 1990</i>
ILUA	Indigenous Land Use Agreement
IUCN	International Union for Conservation of Nature and Natural Resources
JAMBA	Japan–Australia Migratory Birds Agreement
KDC	Kimberley Development Commission
KLC	Kimberley Land Council
KWADS	Kununurra–Wyndham Area Development Strategy
Marubeni	Marubeni Corporation
MfP	Ministry for Planning
NLC	Northern Land Council
NNTTA	National Native Title Tribunal
NRA	National Registration Authority for Agriculture and Veterinary Chemicals
NSCABD	National Strategy for the Conservation of Australia’s Biological Diversity
NTA	<i>Native Title Act 1993</i>
NY No. 11	No. 11 raw sugar futures contract traded on the New York Coffee, Sugar and Cocoa Exchange
ODC	Ord Development Council
OIC	Ord Irrigation Co-operative Ltd
ORIA	Ord River Irrigation Area
PBC	Prescribed Body Corporate
pers. comm.	personal communication
Project	Ord Sugar Project
Project Area	Land that would be developed for farms and infrastructure and associated land that would be managed for conservation
Proponents	Wesfarmers Sugar Company Pty Ltd, Marubeni Corporation and the Water Corporation of Western Australia
Ramsar Convention	Convention on Wetlands of International Importance especially on Water Fowl Habitat, 1975
SCADA	Supervisory, Control and Data Acquisition
TDS	Total dissolved solids
ULV	Ultra-low-volume
WARMS	Western Australian Rangeland Monitoring System
Water Corporation	Water Corporation of Western Australia
Wesfarmers	Wesfarmers Sugar Company Pty Ltd

Vegetation Associations

Grasslands and Sedgeland

- G1** Dense Grassland mosaic dominated by *Heteropogon contortus*, *Iseilema fragile*, *Chrysopogon fallax* or *Sorghum timorense*; Soil Unit 1.
- G2** Dense Grassland of *Themeda triandra*, *Dichanthium sericeum* var. *polystachyum*, *Sorghum timorense* and *Chrysopogon fallax*; Soil Unit 3c.
- G3** Open Grassland of *Themeda triandra* over *Eriachne* sp.; Soil Unit 1.
- G4** Open annual grassland of *Sorghum timorense* over dense *Chrysopogon fallax*; Soil Unit 5c.
- G5** Open Grassland of *Imperata cylindrica* over *Xerochloa imberbis* and *Sporobolus virginicus*; Soil Unit 7a.
- G6** Mixed Sedgeland and Grassland of *Eriachne sulcata*, *Eleocharis dulcis* and *Eleocharis* sp. B (Kimberley Flora) with emergent *Corymbia confertiflora*; Soil Unit 5c/4d.

Grasslands with Emergent Trees

- GT1** Tall Grassland of *Sorghum timorense*, *Aristida latifolia* and *Heteropogon contortus* with emergent *Eucalyptus microtheca*; Soil Unit 1.
- GT2** Dense grassland of *Iseilema vaginiflorum*, *Aristida latifolia*, *Sorghum timorense*, *Themeda triandra* with emergent *Eucalyptus microtheca*, *Excoecaria parvifolia*, *Atalaya hemiglaucula* and *Bauhinia cunninghamii*; Soil Unit 1.
- GT3** Grassland of *Panicum decompositum*, *Heteropogon contortus*, *Themeda triandra* and *Iseilema vaginiflorum* with emergent scattered *Eucalyptus microtheca* and *Corymbia bella* in Soil Unit 1; the raised eastern bank above Milligan Lagoon. Open Sedgeland dominated by *Eleocharis dulcis* and *Schoenoplectus praelongatus* with emergent *Excoecaria parvifolia* and *Barringtonia acutangula* on the edge of Milligan Lagoon.
- GT4** Grassland dominated by *Themeda triandra* and *Aristida latifolia* with emergent trees of *Eucalyptus microtheca*; Soil Unit 5a.
- GT5** Grassland dominated by *Iseilema vaginiflorum* with emergent *Eucalyptus microtheca* and emergent to dense *Excoecaria parvifolia*; Soil Unit 5b.
- GT6** Grassland of *Cymbopogon procerus* and *Themeda triandra* with emergent *Bauhinia cunninghamii* and *Acacia ditricha*; Soil Unit 4a.
- GT7** Grassland of *Bothriochloa bladhii*, *Themeda triandra* and *Ophiuros exaltatus* with emergent *Eucalyptus microtheca*, *Acacia ditricha* and *Bauhinia cunninghamii*; Soil Unit 7a.
- GT8** Grassland of *Themeda triandra*, *Iseilema vaginiflorum* and *Aristida latifolia* with scattered *Bauhinia cunninghamii*, *Acacia ditricha* and *Corymbia bella*; Soil Unit 1.
- GT9** Open tussock and annual grassland of *Eulalia aurea*, *Panicum decompositum* and *Sorghum timorense* with emergent *Corymbia bella* and *Parkinsonia aculeata* at a Swamp; Soil Unit 1.

- GT10** Open Hummock grassland dominated by *Plectrachne bynoei* with Open Shrubland of *Calytrix exstipulata* and scattered low trees of *Buchanania obovata*, *Owenia vernicosa* and *Eucalyptus confertiflora*; Soil Unit 6.
- GT11** Open annual grassland and herbfield of *Neptunia monosperma* with emergent trees of *Atalaya salicifolia* and *Excoecaria parvifolia*; Soil Unit 9c.
- GT12** Open Grassland of *Sehima nervosum* and *Themeda triandra* with scattered trees of *Bauhinia cunninghamii*, *Adansonia gregorii*, *Corymbia foelscheana* and *Eucalyptus microtheca*; Soil Unit 2b.
- GT13** Moderately dense tussock and annual grassland of *Chrysopogon fallax*, *Themeda triandra* and *Iseilema fragile* with emergent low trees of *Corymbia bella*, *Excoecaria parvifolia* and *Bauhinia cunninghamii*; Soil Unit 5c.
- GT14** Open grassland and herbland of mixed species with emergent *Eucalyptus microtheca*, *Corymbia bella* and *Adansonia gregorii*; Soil Unit 11 at the base of a rock outcrop.

Woodlands

Woodlands of *Eucalyptus microtheca*, *Atalaya hemiglaucula*, *Bauhinia cunninghamii* and *Excoecaria parvifolia*

- Em1** Dense Woodland of *Eucalyptus microtheca* over a grassland of *Iseilema vaginiflorum* and *Aristida latifolia*; Soil Unit 1.
- Em2** Woodland of *Eucalyptus microtheca* over open *Bauhinia cunninghamii* and *Atalaya hemiglaucula* over a grassland of *Chrysopogon fallax*, *Iseilema vaginiflorum* and *Brachyachne convergens*; Soil Unit 1g.
- Em3** Woodland of *Eucalyptus microtheca* over a grassland of *Themeda triandra* and *Chrysopogon fallax*; Soil Unit 4b.
- Em4** Woodland of *Eucalyptus microtheca* and *Excoecaria parvifolia* over sedge-grassland of *Aristida latifolia*, *Panicum decompositum*, *Chrysopogon fallax*, *Panicum laevinode*, *Sorghum timorense* and *Iseilema fragile*; Soil Unit 5a.
- Em5** Woodland of *Eucalyptus microtheca* and *Bauhinia cunninghamii* over a closed tussock grassland of *Themeda triandra* and *Ophiuros exaltatus*; Soil Unit 7b.
- Em6** Open Woodland of *Eucalyptus microtheca*, *Bauhinia cunninghamii*, *Excoecaria parvifolia* and *Atalaya hemiglaucula* over an open shrubland of *Bauhinia oblongata* subsp. *volucris* open grassland of *Astrebla squarrosa*, *Aristida latifolia* and *Panicum decompositum*; Soil Unit 1 and 1c.
- Em7** Open Woodland of *Eucalyptus microtheca* and *Acacia ditricha* over a tall grassland dominated by *Oryza australiense*, *Sorghum timorense* over *Panicum decompositum*; Soil Unit 1.
- Em8** **Low** Open Woodland of *Eucalyptus microtheca* and *Excoecaria parvifolia* over a dense grassland dominated by *Ophiuros exaltatus*, *Sorghum timorense*, *Oryza australiense* and *Iseilema fragile*; Soil Unit 5b.

Em9 Open Woodland of *Eucalyptus microtheca* over open tussock and annual grassland of *Panicum laevinode*, *Ophiuros exaltatus*, *Cyperus conics* and *Neptunia monosperma*; Soil Unit 5a.

Woodlands of *Eucalyptus microtheca* and *Melaleuca* spp.

EM1 Open Woodland of *Eucalyptus microtheca* over Shrubland of *Melaleuca nervosa* and *Grevillea striata* over a low open grassland of *Themeda triandra*, *Eriachne obtusa* and *Aristida hygrometrica*; Soil Unit 1.

EM2 Woodland of *Eucalyptus microtheca* over a low woodland of *Excoecaria parvifolia*, *Melaleuca viridiflora* and *Terminalia oblongata* subsp. *volucris*; Soil Unit 11.

EM3 Woodland of *Eucalyptus microtheca*, *Melaleuca argentea* and *Lophostemon grandiflorus* subsp. *riparius* over Dense Low Woodland of *Bauhinia cunninghamii*; Soil Unit 7a.

Woodlands of *Eucalyptus microtheca* and Shrubland of *Terminalia oblongata* subsp. *volucris*

ET1 Woodland of *Eucalyptus pruinosa*, *Eucalyptus microtheca* over Open Shrubland of *Terminalia oblongata* subsp. *volucris*, *Bauhinia cunninghamii* and *Carissa lanceolata* over a grassland dominated by *Themeda triandra*, *Sehima nervosum*, *Chrysopogon pallidus* and *Eriachne glauca* var. *glauca*; Soil Unit 5e.

ET2 Woodland of *Eucalyptus microtheca* over *Bauhinia cunninghamii* and *Terminalia oblongata* var. *volucris* over dense grassland of *Themeda triandra* and *Sehima nervosum*; Soil Unit 3c.

ET3 Woodland of *Eucalyptus microtheca* and *Corymbia greeniana* over *Bauhinia cunninghamii*, *Terminalia oblongata* subsp. *volucris* and *Hakea arborescens* over scattered tussocks of *Aristida latifolia*, *Sorghum timorense* and *Iseilema vaginiflorum*; Soil Unit 5a.

ET4 Low open woodland of *Eucalyptus microtheca*, *Bauhinia cunninghamii*, over a Shrubland of *Terminalia oblongata* subsp. *volucris* over dense grassland dominated by *Themeda triandra*, *Aristida latifolia*, *Sehima nervosum*, *Chrysopogon fallax* and *Ophiuros exaltatus*; Soil Unit 4d.

ET5 Open Low Woodland of *Excoecaria parvifolia*, *Bauhinia cunninghamii* over a Shrubland of *Terminalia oblongata* subsp. *volucris* and *Eucalyptus microtheca* over an Open Tussock Grassland of *Chrysopogon fallax*, *Panicum decompositum*, *Astrebla elymoides* and *Iseilema fragile*; Soil Unit 5b and 5bt.

ET6 Open Low Woodland of *Excoecaria parvifolia*, *Bauhinia cunninghamii* and *Eucalyptus microtheca* over a Shrubland of *Terminalia oblongata* subsp. *volucris* and a grassland of *Panicum decompositum*, *Iseilema vaginiflorum* and *Sorghum timorense*; Soil Unit 1.

Woodlands of *Eucalyptus miniata*

Min1 Woodland of *Eucalyptus miniata*, *Eucalyptus tetradonta* and *Terminalia platyphylla* over a shrubland of *Acacia difficilis* over an open grassland of *Aristida* sp.; the Cockatoo Land System.

Min2 *Eucalyptus miniata* low forest over open *Grevillea agrifolia* over *Plectrachne caroliniana* or *Triodia burbridgeana* and *Sorghum* sp. open grassland on a moderate slope of the Cockatoo Land System.

Woodland of *Eucalyptus papuana*

Ep1 Woodland of *Eucalyptus papuana* over a Shrubland of *Flueggia virosa* var. *melanthesoides* over Grassland of *Heteropogon contortus*; Soil Unit 7.

Woodland of *Eucalyptus tetradonta*

Et1 Woodland of *Eucalyptus tetradonta*, *Corymbia greeniana* and *Terminalia canescens* over a shrubland of *Acacia* affin. *aulacocarpa*; Cockatoo Soil Unit.

Woodlands of *Corymbia bella*

Cb1 Open woodland of *Eucalyptus microtheca*, *Corymbia bella*, *Corymbia greeniana*, *Excoecaria parvifolia* and *Bauhinia cunninghamii* over a grassland of *Sehima nervosum* and *Heteropogon contortus*; Soil Units 7a and 7a/b.

Cb2 Woodland of *Eucalyptus microtheca*, *Corymbia greeniana*, *Corymbia confertiflora*, *Corymbia bella* and *Adansonia gregorii* over an open shrubland of *Bauhinia cunninghamii* and a grassland of *Sehima nervosum* and *Themeda triandra*; Soil 7f .

Cb3 Woodland of *Eucalyptus microtheca*, *Corymbia bella*, *Bauhinia cunninghamii* and *Excoecaria parvifolia* over a grassland dominated by *Ophiuros exaltatus*, *Chrysopogon fallax*, *Dichanthium sericeum* var. *polystachion*; Soil Unit 5e.

Cb4 Woodland of *Bauhinia cunninghamii*, *Eucalyptus bigalerita*, *Terminalia grandiflora* and *Corymbia bella* over an open tussock and annual grassland of *Heteropogon contortus* and *Chrysopogon fallax*; Soil Unit 8b.

Cb5 Woodland of *Corymbia bella*, *Eucalyptus pruinosa* and *Melaleuca minutifolia* woodland over dense grassland of *Themeda triandra*; Soil Units 2a and 2a/3a.

Cb6 Open Woodland of *Terminalia platyphylla*, *Corymbia bella* over an open woodland of *Bauhinia cunninghamii* and *Terminalia oblongata* subsp. *volucris* and scattered *Acacia ditricha* over a dense annual and tussock grassland of *Themeda triandra*, *Heteropogon contortus*, *Aristida latifolia* , *Ophiuros exaltatus* and *Sorghum timorense*; Soil Units 4a, 4b and 4c.

Cb7 Open Woodland of *Corymbia bella*, *Corymbia polycarpa*, and *Melaleuca viridiflora* over a dense grassland of *Themeda triandra*; Soil Unit 7a.

Cb8 Open Woodland of *Corymbia bella* and *Acacia ditricha* over a Grassland of *Themeda triandra*, *Ophiuros exaltatus*, *Chrysopogon fallax* and *Cymbopogon contortus*; Soil Unit 1and 5a.

Cb9 Open Woodland of *Corymbia bella*, *Planchonia careya*, *Atalaya salicifolia* and *Acacia ditricha* over tussock grassland of *Themeda triandra*, *Ophiuros exaltatus* and *Eulalia aurea*; Soil Unit 8.

Cb10 Very Open Woodland of *Corymbia bella* over tussock and annual grassland of *Themeda triandra*, *Ophiuros exaltatus* and *Sorghum stipoides*; Soil Unit 9c.

Woodlands of *Corymbia confertiflora*

Cc1 Open Woodland of *Corymbia confertiflora*, *Planchonia careya* and *Terminalia latipes* var. *latipes* over moderately dense *Bauhinia cunninghamii* and a very open tussock grassland of *Heteropogon contortus*, *Themeda triandra* and *Sorghum plumosum*; Soil Unit 2b.

Cc2 Woodland of *Corymbia bella*, *Acacia ditricha*, *Corymbia confertiflora*, *Planchonia careya* and *Bauhinia cunninghamii* over an open grassland of *Themeda triandra*, *Heteropogon contortus* and *Sehima nervosum*; Soil Unit 4d.

Cc3 Woodland of *Corymbia confertiflora*, *Corymbia greeniana* and *Planchonia careya* over scattered mallees of *Corymbia foelscheana* over a grassland of *Heteropogon contortus* and *Sehima nervosum*; Soil 2a.

Cc4 Woodland of *Corymbia confertiflora*, *Eucalyptus microtheca* and *Eucalyptus tectifera* over a Grassland dominated by *Aristida holathera* var. *holathera*, *Themeda triandra*, *Sorghum plumosum* var. *plumosum*; Soil Unit 8a.

Woodlands of *Corymbia tectifica*

Ct1 Woodland of *Eucalyptus tectifica* over open tussock grassland of *Heteropogon contortus*, *Themeda triandra* and *Chrysopogon fallax*, *Themeda triandra*; Soil Unit 2a and 2c.

Ct2 Low Woodland of *Eucalyptus tectifica* over dense tussock and annual grassland of *Themeda triandra*, *Panicum decompositum* and *Sorghum timorense*; Soil Unit 4a.

Woodlands of *Corymbia* sp., *Brachychiton diversifolius* and *Gyrocarpus americanus*

CBG Woodland of *Corymbia* spp. *Brachychiton diversifolius*, *Bauhinia cunninghamii* with scattered taller *Gyrocarpus americanus* subsp. *pachyphyllus* over an open grassland of *Themeda triandra*; Soil Unit 6e.

Woodland of *Bauhinia cunninghamii*

Bc1 Low Woodland of *Bauhinia cunninghamii* over tussock and annual grassland of *Iseilema* sp. *Panicum decompositum*, *Sehima nervosum*, *Aristida latifolia*, *Cyperus bifax*, *Sehima nervosum*, *Chrysopogon fallax* and *Sorghum timorense*; Soil Unit 1.

Bc2 Low Shrubland of *Bauhinia cunninghamii* and *Atalaya hemiglauca* over grassland of *Chrysopogon fallax* with lianes of *Rhynchosia fallax*; Soil Unit 1.

Bc3 Low Woodland of *Bauhinia cunninghamii* occasionally with scattered *Acacia ditricha* over grassland of *Themeda triandra* and *Chrysopogon fallax*; Soil Unit 1.

Woodlands of *Excoecaria parvifolia*

- Ex1** Woodland of *Excoecaria parvifolia* with scattered *Corymbia bella* and *Bauhinia cunninghamii* over mixed grass species; Soil Unit 1.
- Ex2** Woodland of *Excoecaria parvifolia* over an open to dense grassland dominated by *Ophiuros exaltatus*, *Iseleima fragile* or *Heteropogon contortus*. Typically this occurs along minor drainage lines within the Grasslands of the Keep River and is an extension of the grassland community G1.
- Ex3** Woodland of *Excoecaria parvifolia* with scattered *Eucalyptus microtheca* over a Low Grassland dominated by *Sehima nervosum* and *Cyperus viscidulus*; Soil unit 1e.
- Ex4** Woodland of *Melaleuca nervosa*, *Excoecaria parvifolia* and *Cathormion umbellatum* over scattered *Strychnos lucida* shrubs and mid-dense **Passiflora foetida* var. *hispida* lianes; Soil Unit 7.

Woodlands of *Melaleuca* species

- Me1** Woodland of *Eucalyptus* sp., *Corymbia* sp., *Terminalia grandiflora*, *Melaleuca nervosa* and *Acacia difficilis* over an open grassland of *Eriachne obtusa*, *Chrysopogon setifolius* and *Aristida holanthera* var. *holanthera*; Soil Type 8e.
- Me2** Low Woodland of *Melaleuca viridiflora* and *Eucalyptus tectifera* over open shrubland of *Acacia difficilis* over open *Plectrachne* sp. and *Fimbristylis* sp.; Soil Unit 7a.
- Me3** Open shrubland of *Melaleuca acacioides* and *Excoecaria parvifolia* over scattered grassland of *Heteropogon contortus*; Soil Unit 7.
- Me4** Woodland of *Melaleuca minutifolia*, *Melaleuca viridiflora*, *Excoecaria parvifolia*, and *Cochlospermum fraseri* over an open to dense grassland of *Themeda triandra* and *Sorghum timorense*; Soil Units 3a/4a.

Woodland of *Buchanania obovata*

- Bo1** Low Woodland of *Buchanania obovata* and *Bauhinia cunninghamii* over Open Grassland of *Sehima nervosum* and *Sorghum stipoides* on a dolomite hill.

Woodlands of *Terminalia canescens*

- Tc1** Low Woodland of *Terminalia canescens* over a very open *Heteropogon contortus* grassland on a sandstone hill on the Knox Creek Plain.

APPENDIX D

REFERENCES

APPENDIX D

REFERENCES

Chapter One

Government of Western Australia and the Government of the Northern Territory. *Terms of Reference for Expressions of Interests in the Development of the Ord River Irrigation Area - Stage 2, 1997.*

International Sugar Organization 1994. *World Sugar Statistics 1955-1994.*

LMC International Ltd 1999. *LMC Commodity Bulletin, Sugar July 1999.*

Chapter Two

Agriculture Western Australia. 1998. *Agriculture in Western Australia.*

Cook, L. A. 1997. 'A report on aerial application for weed insect and disease control currently in use on the Ord River Irrigation Scheme'. Agriculture Western Australia.

Doupé, R.G., M.A. Lund and S.R. Ranford. 1998. *A short-term assessment of point source pollution in the M1 irrigation supply channel with notes on agricultural discharge into the lower Ord River.*

Government of Western Australia and Government of the Northern Territory. 1996. *Ord River Irrigation Project — A review of its Expansion Potential.* Joint publication.

Waters and Rivers Commission. 1998. *A Preliminary Investigation of Fish Kills and Endosulfan levels in the Dunham and Ord Rivers.* In: *Proceedings of the Environmental Symposium "The Issues facing the Ord today"*.

Chapter Three

Bureau of Sugar Experiment Stations 1998. *1997/1998 Annual Report.*

Sherrard, J.H. 1994. *Water Requirements for Irrigated Cropping in the Ord River Irrigation Area.* Western Australian Department of Agriculture.

Chapter Four

Aldrick, J.M. and P.W. Moody. 1977. *Report on the Soils of the Lower Weaber and Keep Plains, N.T.* Animal Industry and Agriculture Branch Department of Northern Territory Darwin, N.T.

Aldrick, J.M., A.J. Clarke, P.W. Moody, M.R.H van Cuylenburg and B.A. Wren. 1978. *Soils of the Ivanhoe Plain, East Kimberley, Western Australia.* Western Australian Department of Agriculture. Technical Bulletin No. 82.

Baker, D.E. and V.J. Eldershaw. 1993. *Interpreting soil analyses for agricultural land use in Queensland.* Department of Primary Industries and Fisheries.

Department of Industries and Development. 1977. *Report on soils of the lower Weaber and Keep Plains, Northern Territory.* Technical Bulletin No. 19.

- Dixon, J. 1996. *Soils of the Weaber Plain East Kimberley, Western Australia Natural Resources Assessment Group March 1996*. Agriculture Western Australia.
- George, P.R. 1983. Unpublished, *Soil Salinity and Sodicity in Relation to Land Use*. Ivanhoe Plain Ord River Project Area. Department of Agriculture.
- Hubble, G.D., R.F. Isbell, and K.H. Northcote. 1983. *Features of Australian Soils*. In: *Soils an Australian Perspective*. Commonwealth Scientific Industry and Research Organisation. Division of Soils, Melbourne.
- Humphreys, B. 1995. *Limestone of the east Kimberley, Western Australia-karst and cave fauna*. Western Australian Museum.
- Hunsigi. 1993. *Production of Sugarcane Theory and Practice*, Advanced Series in Agricultural Sciences 21. Springer-Verlag.
- Lavalle, A.M. 1983. *Review of Land and Water Resources of Ord River Irrigation Area Western Australia*. Report prepared for Booker Agriculture International.
- Riley, I.T., D.A. McGhie, and J.H. Sherrard. 1993. *Soils of the Ord River Irrigation Area*. Department of Agriculture Western Australia.
- Schoknecht, N. and C. Grose. 1996. *Soils of the Knox Creek Plain East Kimberley Western Australia and Northern Territory*. Agriculture, Western Australia. Resource Management Technical Report 153.
- Shaw, R. 1988. *Soil Salinity and Sodicity*. In *Understanding Soils and Soil Data*. Ed I.F. Fergus Australian Society of Soil Science Incorporated Queensland Branch. p109-134.
- Shaw, R.J. and D.F. Yule. 1978. *Assessment of soils for irrigation, Emerald, Queensland*, Agriculture Chemistry Branch Technical Report No. 13, Department of Primary Industries, Queensland.
- Stace, H.T.C., G.D. Hubble, R. Breuers, K.H. Northcote, J.R. Sleeman, M.J. Mulchay and E.G. Hallsworth. 1968. *A Handbook of Australian Soils* Rellim Technical Publications.
- Stewart, G.A. et al. 1970. *Lands of the Ord-Victoria area, Western Australia and Northern Territory*. CSIRO Aust. Land. Research Series. No. 28. Melbourne.

Chapter Five

- ANZECC. 1992. *Australian Water Quality Guidelines for Fresh and Marine Waters*. Australian and New Zealand Environment and Conservation Council.
- Barrett, J.W., S.M. Peterson, and G.E. Batley. 1991. *The Impact of Pesticides on the Riverine Environment with Specific Reference to Cotton-Growing*. A report by Barrett Purcell and Associates with CSIRO Centre for Advanced Analytical Chemistry.
- Chang, H.H. 1998. *Fluvial Processes in River Engineering*. John Wiley & Sons Inc.
- Doupé, R.G., M.A. Lund, and S.R. Ranford. 1998. *A short-term assessment of point source pollution in the M1 irrigation supply channel with notes on agricultural drainage into the lower Ord River*. A report for the Water Corporation of Western Australia.
- Environmental Protection Authority of NSW. 1995. *Draft Environmental Guidelines for Irrigation Farming: General Principles - Draft*. Environmental Protection Authority of New South Wales.

- Field, D.F. 1988. Baseflow Water Quality Surveys in Rivers of the Northern Territory - Volume 12 The Keep River. Report 11/1988. Power and Water Authority Water Directorate, Water Resources Group.
- Gardiner H.G. & Associates. 1998. Issues paper prepared on behalf of Ord Land & Water.
- ID&A. 1996. *Hydraulic Geometry of Brisbane Streams: Guidelines for Natural Channel design*. Part 1 - Guidelines. Final Report for Brisbane City Council.
- Larson, H. 1999. *Keep River Aquatic Fauna Survey*. Museums and Art Galleries of the Northern Territory Research Report No. 4 February 1999.
- Schofield, N., V. Edge, R. Moran. 1998. *Minimising the Impact of Pesticides on the Riverine Environment - Using the Cotton Industry as a Model*. Water January / February 1998.
- Sinclair Knight Merz. 1998. *Ord Irrigation Area Stage 1 - Water and Nutrient Balance Study*. Report prepared for the Water Corporation of Western Australia.
- Water and Rivers Commission. 1999. *Draft Interim Water Allocation Plan - Ord River Western Australia*. Water and Rivers Commission Report WRAP 15.

Chapter Six

- ANZECC. 1992. Australian Water Quality Guidelines for Fresh and Marine Waters.
- Chin, D., G. Humphreys, and P. Jolly. 1997. *Sub-surface Hydrology of the Knox Plain (NT Portion)*, Department of Lands, Planning and Environment, Water Resources Division, Darwin.
- Humphreys, G., S. Tickell, D. Yin Foo, and P. Jolly. 1995. *Sub-surface Hydrology of the Keep River Plains*, Technical Report No 24/95D, Water Resources Division, Power and Water Authority, Darwin.
- Hutson, J.L., and R.J. Wegenet. 1992. *LEACHM - Leaching Estimation and Chemistry Model*. Version 3, New York State College of Agriculture and Life Sciences, Cornell University, Ithaca, New York, USA.
- Laws, A.T., 1991. *The Hydrogeology of the Ord River Irrigation Area*, in conference proceedings "50 Years of Ord Irrigation - Review and Future Perspectives", Kununurra 1991: Western Australia, Minister for North West, Agriculture, Water Resources, Ord Development Council
- Moray, A.J. and G.M. Beere. 1988. *Geology of the Onshore Bonaparte and Ord Basin in Western Australia*, Western Australia Geological Survey, Bulletin 134.
- Nixon, R.D. 1997a. *Ord River Irrigation Area Drilling Project, Bore Completion Report on the Knox Creek Plain*, Water and Rivers Commission Hydrogeology Report No 65.
- Nixon, R.D. 1997b. *Ord River Irrigation Area Drilling Project, Bore Completion Report on the Weaber Plain*, Water and Rivers Commission Hydrogeology Report 66.
- Nixon, R.D. 1997c. *Ord River Irrigation Area Drilling Project, Bore Completion Report on the Ivanhoe Plain*, Water and Rivers Commission Hydrogeology Report 70.
- Nixon, R.D. 1997d. *Ord River Irrigation Area Miscellaneous Data Report on the Weaber and Knox Creek Plains*, Water and Rivers Commission Hydrogeology Report 72.
- Nixon, R.D. 1997e. *Ord River Irrigation Area Drilling Project, Bore Completion Report on the Cave Spring Gap*, Water and Rivers Commission Hydrogeology Report No 71.

O'Boy, C.A. 1997. *Ord River Irrigation Area Test Pumping*, Water and Rivers Commission Hydrogeology Report No 48/1997.

O'Boy, C.A. 1998. *Ord River Irrigation Area Long-term Test Pumping*, Water and Rivers Commission Hydrogeology Report No 125/1998

Sinclair Knight Merz. 1998. *Ord Irrigation Area Stage 1 - Water and Nutrient Balance Study*. Report prepared for the Water Corporation of Western Australia.

Sweet, I.P., J.R. Mendrum, R.J. Bultitude, and C.M Morgan. 1974. *The Geology of the Southern Victoria River Region*, Northern Territory, Australia, Report 167, Bureau of Mineral Resources.

Whitehead, B.R., and G.M. Fahey. 1985. *Geology of the Keep River National Park*, Report 1, Northern Territory Geological Survey.

Chapter Seven

Agriculture and Resource Management Council of Australia and New Zealand, Australian and New Zealand Environment and Conservation Council of Forestry Ministers 1999. *The National Weeds Strategy: A Strategic Approach to Weed Problems of national Significance*.

Aldrick, J.M., and P.W. Moody. 1977. Report on the soils of the lower Weaber and Keep Plains, NT Animal Industry.

Beard, J.S. 1979. Kimberley. Explanatory notes to Sheet 1, 1:1,000,000 Series Vegetation Survey of Western Australia. UWA Press, Nedlands.

Beard, J.S. 1990. *Plant Life of Western Australia*. Kangaroo Press, Sydney.

Braithwaite, R.W., J.M. Lonsdale, and J.A. Esterbergs. 1998. *Alien Vegetation and Native Biota in Tropical Australia: The Spread and Impact of Mimosa Pigra*. Biol. Cons. 48: 189-210.

Brocklehurst, P., B. Harwood, J. Hill, B. Edmeades, and A. Fischer. 1998. Reconnaissance Land Resource Survey of Auvergene Station and Sections of Spirit Hills Station, Northern Territory (unpublished report).

Burbidge, A.A., N.L. McKenzie and K.F. Kenneally. 1991. *Nature Conservation Reserves in the Kimberley Western Australia*. Surrey Beatty and Sones, Canberra.

Connell Wagner Pty Ltd. 1997. *Draft Environmental Impact Statement and Environmental Management Plan Bradshaw Training Area*. Prepared for the Department of Defence.

Connors, G., B. Oliver, and J. Woinarski. 1996. *Bioregions in the Northern Territory: conservation values, reservation status and information gaps*. Report to AVCA National Reserves System Cooperative Program. ANCA Canberra.

Dames and Moore. 1982. Environmental Review and Management Programme, Argyle Diamond Project. Unpublished report to the Department of Conservation and Environment.

Department of Conservation and Land Management. 1992. *A survey of wildlife and vegetation of Purnululu National Park*. Research Bulletin No 6, Perth, Western Australia.

Department of Conservation and Land Management. 1998. Lower Ord Ramsar Site Draft Management Plan.

- Department of Conservation and Land Management. 1999. Max Database Western Australia Herbarium, Como.
- Dixon, J. 1996. *Soils of the Weaber Plain East Kimberley Western Australia*. Agriculture Western Australia. Resource Management Technical Report.
- Ecologia Environmental Consultants. 1997a. *Ord River irrigation Area - Stage 2 M2 Development Area Terrestrial Biological Assessment*. Unpublished report for Department of Resources Development, Perth.
- Ecologia Environmental Consultants. 1997b. *Ord River Irrigation Area - Stage 2 Riverside Development. Terrestrial Biological Assessment*. Unpublished Report for Western Australian Department of Resources Development.
- Ecologia Environmental Consultants. 1999. *Ord River Irrigation Area - Stage 2 M2 Development Area. Terrestrial Biological Assessment Addendum A: Regional Biodiversity and Representation* Commissioned by Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia.
- Forbes, S.J. and K.F. Kenneally. 1986. *A botanical survey of the Bungle Bungle and Osmond Range, south-eastern Kimberley, Western Australia*. Western Australian Naturalist 16: 93-168.
- Gardner, C.A. 1923. *Botanical Notes, Kimberley Division of Western Australia*. Western Australian Forests Department Bulletin No. 32.
- Gowland, P.N. and N. Sonnemann. 1980. *North East Kimberley Reptile and Amphibia list*. Department of Agriculture, Kununurra
- Gowland, P.N., and R.G. Brennan. 1980. *Ord River Irrigation Area Bird list*. Department of Agriculture. Department of Agriculture, Kununurra.
- Gowland. 1980. *Ord River Irrigation Area Mammal list*. Department of Agriculture, Kununurra.
- Henshall, T.S. and A.S. Mitchell. 1979. *Vegetation survey of the Keep River study area*. NT Botanical Bulletin No. 2 Conservation Commission of the Northern Territory.
- Kabay, E.D. and A.A. Burbidge. 1977. *A Biological Survey of the Drysdale River National Park North Kimberley, Western Australia*. Research Bulletin No. 6 Fisheries and Wildlife, Perth.
- Kinhill Pty Ltd 1999. *Ord Sugar Project. Biological Surveys of the Proposed Development Area - May and June 1999*. Commissioned by Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia.
- Larson, H. 1999. *Keep River Aquatic Fauna Survey* Unpublished Report Museum and Art Gallery of the Northern Territory, Darwin.
- McKean, J.L. 1986. Birds of the Keep River National Park (Northern Territory) including the Night Parrot *Geopsittacus occidentalis*. *Aus. Bird Watcher* 11: 114-130
- McKenzie, N.L., R.B. Johnston. and P.G. Kendrick, (eds). 1991. *Kimberley Rainforests of Australia*. Surrey Beatty and Sons, Canberra.
- Miles, J.M. and A.A. Burbidge. 1975. *A Biological Survey of the Prince River Reserve North-west Kimberley Western Australia*. Research Bulletin No. 3 Fisheries and Wildlife, Perth
- Perry, R.A. 1956. *The plant ecology of the Ord-Victoria area, north-western Australia*. MSc Thesis, University of Adelaide.

- Petheram, R.J. and B. Kok. 1991. *Plants of the Kimberley Region of Western Australia*. UWA Press, Nedlands.
- Stewart, G.A., R.A. Perry, S.J. Patterson, J.R. Sleeman, and P. Traves. 1970. Lands of the Ord-Victoria Area, Western Australia and Northern Territory. CSIRO Aust. Land. Res. Ser. No. 28 Melbourne.
- Thackway, R. and I.D. Cresswell, I.D. 1995. An Interim Biogeographic Regionalisation for Australia. ANCA, Canberra.
- Tidemann, S.C., P. Wilson, J. Burgess, S. Kerin, and J. McCartney. 1987. An ecological survey of part of Spirit Hills station, Northern Territory. Conservation Commission Northern Territory, Darwin.
- Wheeler, J.R., B.L. Rye, B.L. Koch, A.J.G. Wilson. 1992. *Flora of the Kimberley Region*. Department of Conservation and Land Management, Perth.
- Wilson, B.A., P.S. Brocklehurst, M.J. Clark, K.J.M Dickinson. 1990. Vegetation Survey of the Northern Territory, Australia Conservation Commission of the Northern Territory Australia.
- Wilson, B.R. et. al. 1981. *Biological survey of Mitchell Plateau and Admiralty Gulf, Kimberley*. Western Australia. Western Australian Museum.
- Wrightman, G.M. 1989. Mangroves of the Northern Territory. Northern Territory Botanical Bulletin No. 7 Conservation commission of the Northern Territory Palmerston Northern Territory.

Chapter Eight

- Beard, J.S. 1979. Kimberley Explanatory notes to Sheet 1, 1:1,000,000 Series Vegetation Survey of Western Australia. UWA Press, Nedlands.
- Dames and Moore. 1982. *Environmental Review and Management Programme, Argyle Diamond Project*. Unpublished report to the Department of Conservation and Land Management.
- Department of Conservation and Land Management. 1992. *A survey of the Wildlife and Vegetation of Purnululu National Park*. Research Bulletin No. 6 Perth WA.
- Department of Conservation and Land Management. 1998. Lower Ord Ramsar Site, Draft Management Plan.
- Ecologia Environmental Consultants. 1997a. *Ord River irrigation Area - Stage 2 M2 development Area Terrestrial Biological Assessment*. Unpublished report for Western Australian Department of Resources Development.
- Ecologia Environmental Consultants. 1997b. *Ord River Irrigation Area - Stage 2 Riverside Development Terrestrial Biological Assessment*. Unpublished report for Western Australian Department of Resources Development.
- Gibert, J., D.L. Danielopol and J.A. Stanford (eds). 1994. *Groundwater Ecology*. Academic Press, London.
- Horner, P. and A. Fisher. 1998. *Ctenotus rimacola* sp. nov. (Scincidae), a new species of lizard with two allopatric subspecies from the Ord-Victoria region of northwestern Australia. Records of the Western Australian Museum 19: 187-200.
- Humphreys W.F. in press b. Physico-chemical profile and energy fixation in an anchialine remiped habitat in north-western Australia. *Journal of the Royal Society of Western Australia*.

- Humphreys, W.F. 1995. *Limestone of the east Kimberley, Western Australia - karst and cave fauna*. WA Museum, Perth.
- Humphreys, W.F., in press a. *The hypogean fauna of the Cape Range peninsula and Barrow Island, north-west Australia*. Pp •••-••• in H. Wilkens, D.C. Culver and W.F. Humphreys (eds). *Ecosystems of the World*, vol 30. *Subterranean Ecosystems*, Chapter 30. Elsevier, Amsterdam.
- Kabay, E.D. and Burbidge, A.A. 1977. *A Biological Survey of the Drysdale River National park North Kimberley, Western Australia*. Research Bulletin No. 6. Fisheries and Wildlife, Perth.
- Kinhill Pty Ltd 1999. *Ord Sugar Project - A Fauna Survey of the M2 Development Area - May and June 1999*. Commissioned by Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia.
- Kitchener, D.J. 1978. *Mammals of the Ord River area, Kimberley, Western Australia*, Rec. West. Aust. Mus. 6: 189-219.
- Larson, H.K. 1995. *Diversity of Fishes in Ranger and Comparison Billabongs, Kakadu National Park: Final Report*. Report to CSIRO, Canberra.
- Larson, H.K. 1996. *Report on the Biological Resources Survey of the Roper River System, Gulf of Carpentaria, Northern territory, Australia: Coastal and Estuarine Fishes*. Report to Mount Isa Mines Holdings, Brisbane.
- Larson, H.K. 1999. *Keep River Aquatic Fauna Survey*. Unpublished report for Kinhill Pty Ltd. Museum and Art Gallery of the Northern Territory
- McKenzie, N.L. R.B. Johnston, and P.G. Kendrick. (eds). 1991. *Kimberley Rainforests of Australia*. Surrey Beatty and Sons, Canberra.
- Miles, J.M. and A.A. Burbidge. 1975. *A Biological Survey of the Prince Regent River Reserve North-west Kimberley, Western Australia*. Research Bulletin No. 3. Fisheries and Wildlife, Perth.
- Northcote, K.H., G.D. Hubble, R.F. Isbell, C.H. Thompson and E. Bettenay. 1960-68. *Atlas of Australian Soils*. CSIRO and Melbourne University Press, Melbourne.
- Puckey, H. Kerin, D. Sand Cheal. 1999. Flat-headed Frog - *Limnodynastes depressus* Proceedings of a Workshop. Northern Territory Parks and Wildlife Commission.
- Schminke, H.K. 1986. Suncarida. Pp 389-404 in L. Botosaneanu (ed.). *Stygofauna Mundi. a faunistic, distributional, and ecological synthesis of the world fauna inhabiting subterranean waters*. E.J Brill / Dr W. Backhuys, Leiden,
- Stewart, G.A., R.A. Perry, S.J. Patterson, J.R. Sleeman, and P. Traves. 1970. *Lands of the Ord-Victoria Area, Western Australia and Northern Territory*. CSIRO Aust. Land Res. Ser. No. 28. Melbourne.
- Wheeler, J.R., B.L. Rye, B.L. Koch, and A.J.G. Wilson. 1992. *Flora of the Kimberley Region*. Department of Conservation and Land Management, Perth.
- Wilson, B.R. et al. 1981. *Biological survey of Mitchell Plateau and Admiralty Gulf, Kimberley, Western Australia*. Western Australian Museum.
- Woinarski, J.C.Z (ed). 1992. *The Wildlife and Vegetation of Purnululu (Bungle Bungle) National Park and Adjacent Area*. Wildlife Research Bulletin No. 6. Department of Conservation and Land Management, Perth.

Chapter Nine

- Allen, G.R. 1982. *Inland fishes of Western Australia*, Western Australian Museum, Perth.
- ANCA. 1995. Guidelines for preparing the second edition of a Directory of Important Wetlands in Australia. Australian Nature Conservation Agency.
- Arthington, A.H. and L.N. Lloyd. 1989. *Introduced poeciliids in Australia and New Zealand in Meffe, G.K. and Snelson, F.F. Ecology and evolution of livebearing fishes (Poeciliidae)*. Prentice Hall, New Jersey.
- Benson, L. 1997. Attachment 3 in Sinclair Knight Mertz. 1997. *Ord Irrigation Area - Stage 2 M2 Development Area*. Unpublished report prepared for the Western Australian Department of Resources Development.
- Brown, G. and H. Larson. 1999. Annexe to MAGNT Research Report No. 4 Keep River Aquatic Fauna Survey, Keep River Aquatic Insects. Unpublished report for Kinhill Pty Ltd.
- Coombes, K. 1996. Population dynamics and ecology of a suite of Atyidae (Crustacea: Decapoda) species in freshwater ecosystems in the Darwin region. Unpublished B.Sc. (Hons.) thesis, Northern Territory University.
- Gowland. 1982. *Lake Kununurra Wetland*. Department of Agriculture WA.
- Halse S.A., R.J. Shiela and G.B. Pearson. 1996. *Waterbirds and aquatic invertebrates of swamps on the Victoria-Bonaparte mudflat, northern Western Australia*. Journal of Royal Society of Western Australia 217-224.
- Hutchins, J.B. 1981. *Freshwater fish fauna of the Mitchell Plateau area, Kimberley, Western Australia* in *Biological Survey of Mitchell Plateau and Admiralty Gulf, Kimberley*, Western Australian Museum, Perth.
- IUCN. 1990. *1990 IUCN Red List of Threatened Animals*. IUCN World conservation Monitoring Centre, Cambridge, United Kingdom.
- Jackson P.D. 1992. *Australian Threatened Fishes 1992 Supplement*. Australian Society for Fish Biology Newsletter, 22 No 2 19-24.
- Jaensch, R.P. 1994. *Waterbird Breeding and populations in the Barkly Lakes Region in the 1993-4 West Season*. Conservation Commission of the Northern Territory, Darwin.
- Kay, W.R., M.J. Smith, A.M. Pinder, J.M. McRae, J.A. Davis and S.A. Halse. 1999. *Patterns of distribution of macroinvertebrate families in rivers of north-western Australia*. Freshwater Biology 299-316.
- Lane, J.A.K. and A.J. McComb. 1988. *Western Australian Wetlands*. In A.J. McComb and P.S. Lake (Eds.) *The Conservation of Australian Wetlands*. Surrey Beatty and Sons Pty Ltd.
- Larson, H. 1999. *MAGNT Research Project No 4. Keep River Aquatic Fauna Survey*. Museums and Art Galleries of the Northern Territory.
- Larson, H.K. 1995. *Diversity of Fishes in Ranger and Comparison Billabongs, Kakadu National Park*; Report to CSIRO, Canberra.

- Larson, H.K. 1996. *Report on the Biological Resource Survey of the Roper River System, Gulf of Carpentaria, Northern Territory, Australia: Coastal and Estuarine Fishes*. Report to Mount Isa Mines Holdings, Brisbane.
- Larson, H.K. 1997. Report to Parks Australia North, on the estuarine fish inventory of Kakadu National Park, Northern Territory, Australia.
- Larson. 1999.
- RAMSAR Convention. 1990. List of Wetlands of International Importance Nominated by the Government of Western Australia and the Conservation and Land Management.
- Richards, K.R. 1986. *A study of the insect pest complex of the Ord River Irrigation Area*. MSc thesis UWA.
- Walker, D.I., F.E. Wells, J. Russell Hanley. (eds). 1996. *Marine Biological Survey of the Eastern Kimberley, Western Australia*. University of Western Australia., Western Australian Museum, Museum and Art Gallery of the Northern Territory.
- Wells, F.E. 1981. *Molluscan Fauna of the Admiralty Gulf, Cape Voltaire, and the Institute Islands, Kimberley, Western Australia. Chitons, Meso- and Meogastropods in Biological Survey of Mitchell Plateau and Admiralty Gulf, Kimberley, Western Australia*. WA Museum, Perth.
- Wheeler, J.R. (ed). 1992. *Flora of the Kimberley Region* Department of Conservation and Land Management, Perth.
- Wilson and Stoddart 1979.
- Wilson, B.R. and J.A. Stoddart. 1979. *A study of the freshwater molluscs of the Ord River Region of Western Australia with reference to their potential as trematode vectors*. Unpublished report Western Australian Museum.

Chapter Ten

- Anon. 1996. *Proposed Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia*. A report by the Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee.
- Bellamy, J.A and J. Robinson. 1998. *Breaking Down Fences: Engaging Stateholders in Integrated Catchment Management*. Paper for Conference on ESD at University of Queensland.
- Burbidge, A.A., N.L. McKenzie, K.F. Kenneally. 1991. *Nature Conservation Reserves in the Kimberley Western Australia*. Department of Conservation and Land Management, Como.
- Commonwealth of Australia. 1996. *The National Strategy for the Conservation of Australia's Biological Diversity*. Commonwealth Department of the Environment, Sport and Territories.
- Connell Wagner Pty Ltd. 1997. *Draft Environmental Impact Statement and Environmental Management Plan Bradshaw Training Area*. Prepared for the Department of Defence
- Connors, G., B. Oliver, and J. Woinarski. 1996. *Bioregions in the Northern Territory: conservation values, reservation status and information gaps*. Report to AVCA National Reserves System Cooperative Program. ANCA Canberra.
- Department of Conservation and Land Management. 1998. Lower Ord Ramsar Site. CALM, Kununurra.

Department of Conservation and Land Management. 1999. *Draft Environmental Weed Strategy*. Unpublished documents by the Department of Conservation and Land Management.

Ecologia Environmental Consultants. 1997. *Ord River Irrigation Area - Stage 2 M2 Development Area Terrestrial Biological Assessment*. Unpublished Report for the Western Australian Department of Resources Development.

Environment Western Australia. 1998. *State of the Environment Report*. Department of Environmental Protection.

Government of Western Australia. 1997a. *State of the Environment Reference Group Draft Working Papers Section 1: Regional Description*. Government of Western Australia, Perth WA.

Government of Western Australia. 1997b. *State of the Environment Reference Group Draft Working Papers Section 7: Maintaining Biodiversity*. Government of Western Australia, Perth WA.

Government of Western Australia. 1997c. *State of the Environment Reference Group Draft Working Papers Section 8: Tracking Progress Toward Ecologically Sustainable Development*. Government of Western Australia, Perth WA.

Halvorsen, L. 1998. *Riverine Vegetation Rids Canefields of Rats*. Australian Landcare April, p 6–7.

Kinhill Pty Ltd 1999. *Ord Sugar Project - A Fauna Survey of the M2 Development Area - May and June 1999*. Commissioned by Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia.

Parks and Wildlife Commission Northern Territory. 1998. *Annual Report for the year ended 30 June 1998*. Northern Territory Government

Parks and Wildlife Commission Northern Territory. 1998. Northern Territory Parks Masterplan Government Printing Office, Northern Territory.

Woinarski, J. and G. Connors. 1997. *Ord River Irrigation Area Stage 2 Options for Conservation*. Parks and Wildlife Commission of the Northern Territory (unpublished report).

Chapter Eleven

Department of Lands Planning and Environment. 1998. *Pastoral Land Monitoring*. Northern Territory Department of Lands Planning and Environment Information Sheet Number 2.

Fisheries Western Australia and Kimberley Development Commission. 1995. *Kimberley Aquaculture Development Plan*. A report by the Fisheries Department of Western Australia and the Kimberley Development Commission.

Kimberley Tourism Association. 1998. *The Kimberley—Far North Western Australia—1998/99 Holiday Planner*.

Ministry for Planning and Kimberley Development Commission 1999 Kununurra-Wyndham Area Development Strategy Discussion Paper. Report prepared by in association with Shire of Wyndham—East Kimberley, Northern Territory Department of Lands, Planning and Environment for the Kununurra-Wyndham Area Development Strategy Steering Committee as part of the Western Australian Planning Commission Strategic Planning Programme. published by the Western Australian Planning Commission, Perth, Western Australia.

Sinclair, T. and C. Ostle. 1998. *Assessment of Potential Sites for Aquaculture in Stage II of the Ord River Irrigation Area*. A report for Fisheries Western Australia.

WA Government. 1964. Ord Irrigation Project. A Case for Financial Assistance from the Commonwealth Government. Government of Western Australia.

WA Government. 1967. Ord Irrigation Project. A Case for Financial Assistance from the Commonwealth Government. Government of Western Australia.

Chapter Twelve

AACM International Pty. Ltd. 1997. *Aboriginal Consultations Ord River Irrigation Scheme Stage II September 1997*. Unpublished report prepared for the Department of Resource Development, Western Australia.

Archae-Aus Pty Ltd. 1999. *A Report on the Monitoring for Aboriginal Archaeological Material for the Ord River Irrigation (Stage 2) First Stage Works, Northern Territory – Western Australian Border, for the Northern Land Council*. January 1999. Unpublished report to the Northern Land Council.

Barber, K. & H. Rumley. 1998. The first stage works programme clearance report. Work programme clearance report of the heritage survey for the proposed Wesfarmers, Marubeni and Water Corporation stage one works of the Ord River Irrigation Area (Stage 2) Project. Unpublished report.

Barber, K. H. Rumley. & L. Strawbridge. 1993. A heritage survey of SECWA's proposed Kununurra diversion dam hydro power station development and the Kununurra to Wyndham power line corridor. Unpublished report.

Commonwealth of Australia. 1978. *Ord River Irrigation Area Review*. A joint Commonwealth and Western Australian Review. Australian Government Printing Service, Canberra.

Dortch, C.E. 1977. *Early and Late Stone Industrial Phases in Western Australia*. In *Stone Tools as Culture Markers*. R.V.S.Wright (ed), Australian Institute of Aboriginal Studies, Canberra, 104-132.

East Kimberley Impact Assessment Project. 1985. Project description and feasibility study. East Kimberley Working Paper No.1. Centre for Resource and Environmental Studies and Australia Institute of Aboriginal Studies Press, Canberra.

Forrest, A. 1880. *Journal of Expedition from De Grey to Port Darwin*. Government Printer, Perth.

Fullagar, R. D. Price, L. Head. 1996. *Early Human Occupation of Northern Australia – Archaeology and Thermo-luminescence Dating of Jinmium Rockshelter, Northern Territory*. In *Antiquity*, No. 70:751-773.

Green, N. 1978. *Aborigines and settlers in the nineteenth century*. In *A New History of Western Australia*. C. Stannage (ed.), University of Western Australia Press, Perth.

Gregory, R. & S. Sutton. 1997. *Final Assessment of the Archaeological Resources of the Keep River Plain and the Knox Plain for the Ord Stage II Project*. Unpublished report prepared for the Northern Territory Department of Primary Industries and Fisheries.

Gregory, R. 1994. *Site patterning in the Ord-Victoria river region: a GIS database*. In *Australian Aboriginal Studies*, Journal of the Australian Institute of Aboriginal and Torres Strait Islander Studies, Canberra, Number 2:51-58.

- Kimberley Land Council. 1992. *Report of Consultations with Kimberley Aboriginal people on the recommendations of the Royal Commission into Aboriginal Deaths in Custody*. Unpublished report.
- Kirkby, I. 1985. *Aboriginal site survey: Kununurra to Halls Creek Road*. Unpublished report.
- Lee, J. 1998. Native Title Determination Application WC94/2 – Miriwung Gajerrong #1. Unpublished report prepared for the Federal Court of Australia.
- Maurice, M. 1985. *Timber Creek Land Claim*. Report No. 21. Australian Government Publishing Service, Canberra.
- Mulvaney, K. 1996. *What to do on a rainy day: reminiscences of Mirriuwung and Gadjerrong artists*. In *Rock Art Research*, Volume 13, Number 1:3-20.
- Novak, V. 1980. *Derby-Wyndham Telecom*. Unpublished report prepared for the Western Australian Museum.
- Quartermaine, G. S. 1990. *Report on a survey for Aboriginal sites, Ord Hydroelectric Project, East Kimberley*. Unpublished report prepared for the Snowy Mountains Engineering Corporation Ltd.
- Quartermaine, G. S. and R. O’Conner. 1991. *Report on a survey for Aboriginal sites Lake Kununurra foreshore study area, East Kimberley*. Unpublished report prepared for the Shire of Wyndham-East Kimberley (2 Volumes).
- Roberts, R. M. Bird, J. Olley, R. Galbraith, E. Lawson, G. Lazlett, H. Yoshida, R. Jones, R. Fullagar, G. Jacobson, and Q. Hua. 1998. *Optical and Radiocarbon Dating for Jinmium Rockshelter in Northern Australia*. In *Nature*, 393:358-362.
- Ross, H. and E. Bray. 1989. *Impact Stories of the East Kimberley*. East Kimberley Working Paper No.28. Centre for Resource and Environmental Studies and Australian Institute of Aboriginal Studies Press, Canberra.
- Shaw, B. 1981. *My Country of the Pelican Dreaming. The Life of an Australian Aborigine of the Gadjerrong, Grant Ngabidj, 1904-1977*. Australian Institute of Aboriginal Studies, Canberra.
- Thoorrbiliny, R. 1987. *The effect of white land use on the Miriwoong people*. In *Aborigines and Development in the East Kimberley*, Australian National University Public Affairs Conference.
- Western Australian Planning Commission and Kimberley Development Corporation. 1999. *Kununurra – Wyndham Area Development Strategy*. Prepared in association with Shire of Wyndham—East Kimberley, Northern Territory Department of Lands Planning and Environment for the Kununurra-Wyndham Area Development Strategy Steering Committee as part of the Western Australian Planning Commission Strategic Programme. Published by the Western Australian Planning Commission, Perth, Western Australia.
- Willis, P. 1980. *Patrons and Riders: Conflicting Roles and Hidden Objectives in an Aboriginal Development Programme at Kununurra*. Unpublished MA Thesis, Australian National University.

Chapter Thirteen

- Australian Environmental Council and National Health and Medical Research Council. 1986. *National guidelines for control of emission of air pollutants from new stationary sources. Recommended methods for monitoring air pollutants in the environment.* 1985. Canberra: Australian Government Publishing Service.
- Barratt P. 1998. *Implications of the Kyoto Protocol for Australian Government and policy makers.* Paper delivered to the Greenhouse Beyond Kyoto - Conference, 1998.
- Bureau of Meteorology. 1998. *Wind frequency analyses and wind roses between 1986 and 1998 for Kununurra Aero.*
- Chapman L.S., M.B.C. Hayson, and P.G. Stafigna. 1992. *N cycling in cane fields is N labelled trash and residual fertiliser*, Proceedings of the Society of Sugar Cane Technologists 1992.
- Cook L. A. 1997. *A report on aerial application for weed insect and disease control currently in use on the Ord River Irrigation Scheme.* Agriculture WA, April 1997.
- Department of Resources Development. 1996. *Ord River Irrigation Project, A review of its expansion potential, Government of Western Australia, August 1996.*
- Howden M.S., D.H. White, G.M. McKeon, J.C. Scanlan and J.O. Carter. 1994. *Methods for exploring management options to reduce greenhouse emissions from tropical grazing systems.* Journal of Climatic Change 27:49-70, 1994.
- Langton, M. 1998. *Burning Questions - Emerging Environmental Issues for Indigenous Peoples in Northern Australia.* Centre for Indigenous Natural and Cultural Resource Management (CINCRM).
- Weier K.L. 1998. *Sugar cane fields: sources or sinks for greenhouse gas emissions*, CSIRO Australia, 1998.

Chapter Fourteen

- Aldred J. et al. 1992 *Australian encephalitis: sentinel chicken surveillance programme—serological results for March 1992*, Communicable Diseases Intelligence (Australia) 16, 169.
- Broom A. K. et al. 1995. *Two possible mechanisms for survival and initiation of Murray Valley encephalitis virus activity in the Kimberley region of Western Australia.* American Journal of Tropical Medicine and Hygiene, 53, 95–99.
- Broom A. et al. 1998. *Report of surveillance of mosquito-borne virus activity in the proposed extension of the Ord River Irrigation area near Kununurra, 1996-97.* (not yet published)
- Broom, A.K. and M.C. Lindsay. 1998. *Ord River Irrigation Area Stage II: monitoring the impact of the development on mosquito-borne virus activity and the risk to human health.* Arbovirus Surveillance and Research Laboratory, Department of Microbiology, The University of Western Australia, Perth.
- Edge, V.E. 1996. *Environmental Issues Facing the Cotton Industry Related to Pesticide Use.* Proceedings of the Eighth Australian Cotton Conference, gold Coast, Australia 14-16 August 1996. pp. 47-54.

- Mackenzie J. S. and A.K. Broom. 1999. *Ord River irrigation area: the effect of dam construction and irrigation on the incidence of Murray Valley encephalitis virus*. In: Water Resources - Health, Environment and Development (B.H. Kay ed). E & FN Spon, London, pp108–122.
- Mackenzie J. S. et al. 1992. *Australian encephalitis: sentinel chicken surveillance programme*. Communicable Diseases Intelligence (Australia) 16, 55–57.
- Mackenzie J. S. 1998. *Arbovirus in the Australian region, 1990 to 1998*. Communicable Diseases Intelligence (Australia) 22, 93–100.
- Schofield, N.J. and B.W. Simpson 1996. Pesticides—An Emerging Issue for Water and the Environment. 23rd Hydrology and Water Resources Symposium, Hobart, Australia 21-24 May 1996. pp. 229-236.
- Stanley N. F. 1972; *Ord River ecology*. Search 3, 7–12.
- Woods, N and R. Lisle. 1988. *Pilots and Operators Manual*. Aerial Agricultural Association of Australia, Sydney.
- Woods, N. and G. Dorr. 1997. *Aerial spray drift under the spotlight*. Farming Ahead No.62, 57-59.
- Wylie, P. 1997. *Avoiding spray drift onto fodder crops*, Lotfeeding, February 1997.

Chapter Fifteen

- Australian Bureau of Statistics. 1995 *Census of Population and housing*. Canberra Australian Bureau of Statistics.
- Beckwith & Associates 1997. *Ord River Irrigation Area Stage 2 Expansion - Social Impact Assessment*. Report prepared for the Western Australian Department of Resources Development, Perth Western Australia.
- Kewagam Research. 1996. *Ord River Fishing Survey*. A Report to the East Kimberly Recreational Fishing Advisory Council.
- Kimberley Development Commission and Department of Commerce and Trade 1999. *Kimberley Economic Perspective*. An Update on the Economy of WA's Kimberley Region.
- Kimberley Development Commission and Department of Commerce and Trade. 1996. *Kimberley Economic Perspective*. An Update on the Economy of WA's Kimberley Region.
- Kimberley Development Commission. 1993. *Kimberley Population and Settlement Technical Paper*. Perth.
- Kimberley Development Commission. 1996a. *Kimberley Economic Perspective*. An update on the economy of Western Australia's Kimberley Region.
- Kimberley Development Commission. 1996b. *The Economic Impact of Irrigated Agriculture in the Ord River Area*. Technical Paper.
- Kimberley Development Commission. 1997. *Kimberley Economic Development Strategy*. Perth.
- Ministry for Planning and Kimberley Development Commission 1999. *Kununurra-Wyndham Area Development Strategy*. Report prepared in association with Shire of Wyndham—East Kimberley, Northern Territory Department of Lands, Planning and Environment of the Kununurra-Wyndham

Area Development Strategy Steering Committee as part of the Western Australian Planning Commission, Perth, Western Australia.

Chapter Sixteen

Crabb, P. 1997. *Murray Darling Basin Resources*. Murray Darling Basin Commission, Canberra.

Chapter Seventeen

There are no references for this Chapter.

APPENDIX E

ORGANISATIONS CONSULTED DURING ERMP/EIS PREPARATION

APPENDIX E

ORGANISATIONS CONSULTED DURING ERMP/EIS PREPARATION

Aboriginal Affairs Department (WA)
Aboriginal Areas Protection Authority
Aboriginal Legal Service of Western Australia
Agriculture Protection Board (WA)
Agriculture Western Australia
Australian Conservation Foundation
Australian Heritage Commission
Booker Tate Limited
Care of the Ord Valley Environment
Commissioner for Soil and Land Conservation
Conservation Council of Western Australia
Consolidated Pastoral Company (lessee of Carlton Hill Station, Ivanhoe Station and sub lessee of Spirit Hills Station)
Department of Conservation and Land Management (WA)
Department of Environmental Protection (WA)
Department of Land Administration (WA)
Department of Lands Planning and Environment (NT)
Department of Minerals and Energy (WA)
Department of Mines and Energy (NT)
Department of Resources Development (WA)
Department of Transport (Maritime) (WA)
Department of Transport and Works (NT)
East Kimberley Recreational Fishing Group
Environment Australia
Environmental Protection Authority (WA)
Fisheries Western Australia
Health Department of Western Australia
Heritage Council of Western Australia
Joorook Ngarni Aboriginal Corporation
Kimberley Development Commission
Kimberley Land Council
Kimberley Region Economic Aboriginal Corporation
Kununurra Rotary
Legune Station

Mains Roads Western Australia
Ministry for Planning (WA)
Mirima Dawang Woorlab-Gerring Language Centre
Miriuwung and Gajerrong Families Heritage and Land Council
National Native Title Tribunal
Northern Land Council
Northern Territory Land Corporation
Office of Resource Development
Office of Water Regulation (WA)
Ord Development Council
Ord Irrigation Cooperative Ltd
Ord Land and Water Steering Committee
Ord River District Co-operative Ltd
Ord River Grain Pool
Ord River Irrigation Area Land Conservation District Committee
Parks and Wildlife Commission of the Northern Territory
Shire of Wyndham – East Kimberley
South West Irrigation
Steering Committee for the Land and Water Management Plan
Telstra
Tropical Agriculture Team
University of Western Australia (Arbovirus Surveillance and Research Laboratory, Department of Microbiology)
Warrangarri Aboriginal Corporation
Water and Rivers Commission
Western Power
Wyndham Action Group
Wyndham Port Authority

APPENDIX F

STUDY TEAM

APPENDIX F

STUDY TEAM

KINHILL PTY LTD

Management

G. R. Puglisi	Project Manager
Dr A. R. Milton	Project Director
T. R. Salmon	Project Engineer

Technical

J. S. Abbott	Irrigation and sodicity issues
Dr R. J. Anderson	Biological environment
Dr E. M. Bennett	Biological environment
G. Boyer	Community issues
A. T. Brown	Biological environment
I. Cameron	Air quality and public health
P. G. Ellery	Biological environment
C. N. Gomes	Surface water modelling
J. C. Greig	Editing
C. F. Harris	Library
W. N. Horwood	Water quality
S. J. Kenway	Physical environment
R. S. Pyle	Biological environment
Dr K. Zic	Groundwater and surface water modelling

Subconsultants

L. D. Ahearn Nature Scope Pty Ltd	Technical Review (biological environment)
Dr R. E. Black RE Black Consultants Pty Ltd	Technical Review
B. A. Boyes Groundwater Services Pty Ltd	Groundwater environment

S. Churchill S. A. Development of Natural Resources and Environment	Biological survey (bats)
G. Connell Ecologia Environmental Consultants	Regional biodiversity
N. Green Anthropos Australis Pty Ltd	Anthropology
Dr R. Hart Hart Simpson Pty Ltd	Biological survey (mammals)
Dr W. F. Humphreys Museum of Natural Science	Stygofauna
L. Lumsden Arthur Rylah Institute for Environmental Research	Biological survey (bats)
Dr H. Larson, P. Horner and G. Brown Museums and Art Galleries of the Northern Territory	Aquatic environment
C. Martens and D. Watts Queensland Department of Natural Resources	Geographical information system based graphics
J. Porter Frog Design	Graphics
P. Robertson Wildlife Profiles Pty Ltd	Biological survey (herpetofauna)
G. Harold Malloch Fauna	Biological survey (herpetofauna)

ACKNOWLEDGEMENTS

The following organisations are gratefully acknowledged for contributing background information used in compiling this ERMP/EIS:

Book Tate Limited - sugar cane cultivation, farm management and sugar milling.

Sinclair Knight Merz - unpublished draft Public Environmental Report for the Project Area commissioned by the Western Australia Department of Resource Development.

APPENDIX G

WATER QUALITY DATA

**ORD RIVER IRRIGATION
AREA STAGE 2
PROPOSED DEVELOPMENT
OF THE M2 AREA**

**A compilation of Water Quality
Data for the Keep River and
other watercourses**

Prepared for:

**WESFARMERS LIMITED,
MARUBENI CORPORATION AND THE WATER
CORPORATION OF WESTERN AUSTRALIA**
Level 7, 40 The Esplanade
Perth WA 6000

Prepared by:

Kinhill Pty Ltd
ACN 007 660 317
47 Burswood Road, Victoria Park WA 6100
Telephone 08 9362 5900, Facsimile 08 9362 5627

August 1999

1 Scope

This document provides a compilation of water quality data for the Keep River and other watercourses in the vicinity of the M2 Development Area of the Ord River Irrigation Scheme. It also contains water quality data from Stage One of the Ord River Irrigation Area.

The data is presented according to the source of the data as follows:

- Table G.1 Field (1998)
- Table G.2 Ribbons of Blue (1995 and 1997)
- Table G.3 for M1 Channel collected by the Water Corporation (December 1995 to July 1996), Ord Irrigation Co-operative Limited (April 1996 to February 1997) and CSR Limited (April 1996 to November 1996).
- Table G.4 Department of Lands, Planning and Environment (January 1995 to October 1996)
- Table G5 Department of Lands, Planning and Environment (1997 to 1998)
- Table G.6 Larson (1999).

2 References

Field, D.G. 1998 Baseflow Water Quality Surveys in Rivers of the Northern Territory - Volume 12 The Keep River. Report 11/1988. Power and Water Authority Water Directorate, Water Resources Group.

Larson, H. 1999, Keep River Aquatic Fauna Survey. Museums and Art Galleries of the Northern Territory Research Report No. 4 February 1999.

Table G.1 Water Quality Data from Field (1988)

Watercourse	Distance from River Mouth (km)	Sample Point	Conductivity (µS/cm)	Temp (deg Cel)	pH	Dissolved Oxygen (% sat)	Turbidity (NTU)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Total hardness (mg/L)	Total Alkalinity (mg/L)	Total Iron (mg/L)	Silica (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Nitrate (mg/L)	Phosphate (µg/L)	Bicarbonate (mg/L)	Fluoride (mg/L)	Sodium Chloride (mg/L)
Keep River	33	1	37600	22.9	8.4	100	57					4200	139			11860			13	169		19542
Keep River	38	2	13880	18.4	8.6	100	5					1750	119			4600			9	145		7591
Keep River	43	3	240	21.7	8.4	88	16	20	4	20	13	102	117	7	16	18	12	1	9	143	0.4	30
Keep River	140	4	485	17.3	8.4	95	4	29	4	44	31	228	265	<0.1	23	16	13	<1	23	323	0.3	25
Keep River	144	5	450	25.3	8.5	150	2	31	4	46	28	226	260	0.1	29	14	13	<1	6	317	0.2	21
Keep River	150	6	380	25.3	8.4	89	2	36	4	34	25	179	230	<0.1	33	14	8	<1	14	280	0.2	23
Keep River	156.5	7	410	22.4	8.4	99	1	35	4	32	28	190	245	0.1	43	12	8	<1	33	299	0.4	20
Keep River	160.5	8	510	24.4	8.1	100	1	30	3	49	35	260	305	<0.1	58	8	10	<1	23	372	0.9	13
Keep River	163	9	417	24	8.1	110	1	23	3	45	26	216	247	<0.1	52	6	9	<1	35	301	0.3	8
Sandy Creek	21	9A	36900	22.3	8.5		16					4260	130			12700			8	159		20949
Sandy Creek	25	9A2	28700	24.4	8.4		11					3230	131			9250			<5	160		15246
Sandy Creek	28	9A3	13700	22.3	8.5		16	2320	150	128	298	1502	117	0.3	12	4190	644	2	8	143	0.7	6910
Sandy Creek	30	9A4	190	24.1	8.3	85	5	18	4	14	11	78	75	<0.1	11	25	10	1	15	91	0.9	40
Sandy Creek	35	9A5	98	24.8	8.1	100	2	5	3	14	10	76	73	<0.1	12	7	7	<1	14	89	<0.1	10
Sandy Creek	42	9A6	100	24.4	8.2	97	2	4	3	14	10	77	72	0.2	15	6	6	<1	15	88	0.7	10
Sandy Creek	50	9A7	100	22.1	9.1	99	1	4	2	13	10	74	70	0.3	15	6	6	<1	16	85	0.3	10
Sandy Creek	61	9A8	110	21.4	7.9	98	3	3	2	14	10	76	72	0.3	13	6	7	<1	13	88	0.4	8
Sandy Creek	74	9A9	52	23.3	7.8	110	3	5	2	7	5	37	38	0.6	15	8	4	<1	19	46	0.1	12
Sandy Creek	90.5	9A10	340	22.4	7.8	87	1	6	4	33	32	206	198	0.1	13	12	10	<1	14	241	0.4	18
Sandy Creek	72	9AA	300	23.7	8.3	98	1	5	3	27	29	187	178	<0.1	14	8	15	<1	25	217	0.2	10
Sandy Creek	74	9AB	210	24.5	8.5	110	8	2	3	27	19	141	140	<0.1	15	6	7	<1	15	171	0.1	8
Sandy Creek	82	9AC	<5	22.6	6.8	94	1	2	1	<1	<1	3	5	0.1	12	4	<1	<1	11	6	0.2	7
Sandy Creek	86	9AD	40	24	7.4	82	6	5	2	7	4	32	30	0.5	14	6	3	<1	14	37	0.2	10
Sandy Creek	91	9AE	420	21.3	8.2	104	1	8	4	36	38	243	233	<0.1	11	18	11	<1	24	284	0.1	28
Moriarty Creek	147	9B	560	17.2	8.3	83	1	38	4	52	36	267	326	<0.1	46	12	11	<1	25	397	0.5	20
Moriarty Creek	154	9B2	440	19.6	7.5	73	1	27	3	48	26	220	258	<0.1	42	13	9	<1	23	314	0.5	20
Moriarty Creek	154	9BA	440	19.7	7.6	88	1	25	2	45	27	218	260	<0.1	38	6	5	<1	45	317	0.3	10
Keep River	146	9C	540	22.2	8.2	85	2	42	5	43	34	248	303	0.2	32	16	11	1	19	369	0.4	26
Keep River	155	9D	540	22	8.3	100	2	44	2	53	29	250	324	<0.1	59	10	15	<1	25	395	0.2	16
Keep River	156.5	9E	380	22.8	8.3	108	2	26	3	41	24	196	237	<0.1	43	8	10	<1	22	289	0.4	12
Keep River	161	9F	740	25.1	7.7	92	2	50	1	68	50	360	433	<0.1	72	18	12	<1	56	528	0.6	28

Table G.2 Ribbons of Blue Water Quality Data (1995 and 1997)

Water course	Month	Year	Nitrate	Phosphate
			(mg/L0	(mg/L)
Border Creek	Feb	1997	0.557	0.150
Keep River	Feb	1997	0.620	0.057
Keep River (upstream of ORIA M2 Development Area)	Feb	1997	0.512	0.031
Milligan Lagoon	Feb	1997	0.492	0.044
Knox Creek	Feb	1997	0.500	0.039
Keep River (Policemans Waterhole)	Jan	1995	0.426	0.046
Keep River (upstream of Legune Road crossing)	Jan	1995	0.648	0.049

Table G.3 Monthly Water Quality Data from the M1 Channel

Source of Data	Month	Year	Conductivity (µS/cm)	pH	Turbidity (NTU)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Total hardness (mg/L)	Total Alkalinity (meq)	Nitrate (mg/L)	Phosphate (mg/L)
Ord Irrigation Co-operative Ltd	January											0.405	0.017
Ord Irrigation Co-operative Ltd	January											0.249	0.009
Ord Irrigation Co-operative Ltd	January											0.303	0.022
Ord Irrigation Co-operative Ltd	January											0.254	0.021
Ord Irrigation Co-operative Ltd	February											0.210	0.012
Ord Irrigation Co-operative Ltd	February											0.307	0.010
Ord Irrigation Co-operative Ltd	February											0.505	0.009
Ord Irrigation Co-operative Ltd	March											0.264	0.021
Ord Irrigation Co-operative Ltd	April											0.026	0.027
Ord Irrigation Co-operative Ltd	May											0.198	0.027
Ord Irrigation Co-operative Ltd	June											0.163	0.009
Ord Irrigation Co-operative Ltd	July											0.165	0.008
Ord Irrigation Co-operative Ltd	September											0.396	0.006
Ord Irrigation Co-operative Ltd	November											0.276	0.009
Ord Irrigation Co-operative Ltd	December											0.285	0.017
Water Corporation	February											0.223	0.014
Water Corporation	April											0.238	0.011
Water Corporation	May											0.15	0.009
Water Corporation	June											0.2	
Water Corporation	July											0.17	0.003
Water Corporation	October											0.28	0.009
Water Corporation	November											0.189	0.013
Water Corporation	December											0.179	0.005
Water Corporation	December											0.155	0.0043
CSR Limited	April											0.2	0.02
CSR Limited	May											0.3	0.06
CSR Limited	June											0.2	0.02
CSR Limited	July											0.2	
CSR Limited	August											0.2	0.02
CSR Limited	September											0.2	0.02
CSR Limited	October												0.03
Water Corporation	November	98	270	9	1	22	3	22	10	90	2	<0.05	

Source: Water Corporation - M1 Channel upstream of town effluent disposal taken between December 1995 and July 1996; Ord Irrigation Co-operative Limited - M1 offtake between April 1996 and February 1997; CSR Limited - M1 offtake between April 1996 and November 1996

Table G.4 Water Quality Data from Department of Lands, Planning and Environment January 1995 to October 1996

Watercourse	Description	Month	Year	Conductivity (µS/cm)	Temp (Celcius)	pH	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Nitrate and Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Free reactive phosphorus (mg/L)
MR-KP-01	Keep River (Policemans) Waterhole	7	95	127	25.2	7.75	8	13	0.013	0.339	0.059	0.28	0.002
MR-KP-01	Keep River (Policemans) Waterhole	11	95	209	32.6	8.28	6.63	12	0.013	0.245	0.005	0.24	0.006
MR-KP-01	Keep River (Policemans) Waterhole	7	96	134	25.2	7.86	7.91	8					
MR-KP-01	Keep River (Policemans) Waterhole	10	96	173	32.9	8.1	6.65	11					
MR-KP-02	Keep River (Keep Yard u/s Legune Rd crossing)	7	95	182	22.5	7.76	7.95	19	0.018	0.355	0.005	0.35	0.002
MR-KP-02	Keep River (Keep Yard u/s Legune Rd crossing)	11	95	313	33.3	8.37	6.55	22	0.008	0.281	0.001	0.28	0.003
MR-KP-02	Keep River (Keep Yard u/s Legune Rd crossing)	7	96	210	24.4	8	9.05	20					
MR-KP-02	Keep River (Keep Yard u/s Legune Rd crossing)	10	96		33	8.05	6.6	39					
MR-KP-03	Bubble Bubble Springs	7	95	210	23.7	7.56	5.9	10	0.013	0.084	0.004	0.08	0.004
MR-KP-03	Bubble Bubble Springs	11	95	316	30.1	7.93	5.25	2	0.009	0.123	0.003	0.12	0.007
MR-KP-03	Bubble Bubble Springs	7	96	230	20.3	8.16	8.45	10					
MR-KP-03	Bubble Bubble Springs	10	96	298	30.1	7.55	4.58	0					
MR-KP-04	Keep River (Milligan Lagoon)	7	95	45	23.4	6.94	6	10	0.028	0.444	0.004	0.44	0.007
MR-KP-04	Keep River (Milligan Lagoon)	11	95	73	28.3	6.8	4.3	11	0.024	0.712	0.002	0.71	0.004
MR-KP-04	Keep River (Milligan Lagoon)	7	96	51	23.6	7.24	7.72	8					
MR-KP-04	Keep River (Milligan Lagoon)	10	96	51	33.3	6.69	2.9	1					
MR-KP-05	Alligator Springs Waterhole	7	95	49	27.1	6.02	4.7	10	0.03	0.352	0.002	0.35	0.009
MR-KP-05	Alligator Springs Waterhole	11	95	77	33.4	5.84	6.03	10	0.031	0.481	0.001	0.48	0.01
MR-KP-05	Alligator Springs Waterhole	7	96	87		5.67	5.64	5					
MR-KP-05	Alligator Springs Waterhole	10	96	112		5.03	6.93	3					

Table G.5 Water Quality Data from Department of Lands, Planning and Environment 1997–1998

Watercourse	Sample Location	Month	Year	Conductivity (µS/cm)	pH	Turbidity (NTU)	Nitrate, NO3 (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)
Keep River	G8100226									
Keep River	G8100227	Dec	97	304			19.0	0.054	37	
Keep River	G8100228	Dec	97	290			2.9	0.022	61	
Keep River	G8100229	Dec	97	290			8.3	0.294	71	
Keep River	G8100230	Dec	97	187			3.7	0.070	88	
Keep River	G8100231	Dec	97	153			1.9	0.082	161	
Keep River	G8100232	Dec	97	107			6.0	0.101	254	
Keep River	G8100233	Dec	97	92			4.4	0.110	508	
Keep River	G8100234	Dec	97	83			<0.2	0.066	253	
Keep River	G8100235	Dec	97	68			3.3	0.057	210	
Keep River	G8100236	Dec	97	67			3.6	0.064	193	
Keep River	G8100237	Dec	97	67			1.4	0.062	180	
Keep River	G8100238	Dec	97	69			2.3	0.086	255	
Keep River	G8100239	Dec	97	77			2.8	0.104	394	
Keep River	G8100240	Dec	97	54			7.1	0.095	381	
Keep River	G8100241	Dec	97	80			<0.2	0.048	101	
Keep River	G8100242	Dec	97	54			4.8	0.540	225	
Keep River	G8100243	Dec	97	58			3.4	0.035	66	
Keep River	G8100244	Dec	97	55			5.7	0.070	249	
Keep River	G8100245	Dec	97	61			2.3	0.059	166	
Keep River	G8100246	Dec	97	86			<0.2	0.068	155	
Keep River	G8100247	Dec	97	65			1.3	0.052	118	
Keep River	G8100248	Dec	97	92			4.4	0.072	150	
Keep River	G8100249	Dec	97	95			3.2	0.085	221	
Keep River	G8100250	Jan	98	60			3.4	0.122	127	
Keep River	G8100251	Jan	98	47			<0.2	0.069	129	
Keep River	G8100252	Jan	98	50			2.0	0.084	428	
Keep River	G8100253	Jan	98	56			0.6	0.214	1821	
Keep River	G8100254	Jan	98	52			0.2	0.084	1313	
Keep River	G8100255	Jan	98	48			2.7	0.140	819	
Keep River	G8100256	Jan	98	54			3.3	0.136	622	
Keep River	G8100257	Jan	98	45			0.7	0.110	777	
Keep River	G8100258	Jan	98	48			2.7	0.096	646	
Keep River	G8100259	Jan	98	45			1.8	0.090	432	
Keep River	G8100260	Jan	98	56			0.2	0.064	186	
Keep River	G8100261	Feb	98	55			2.0	0.074	181	1.00
Keep River	G8100262	Feb	98	52			1.0	0.062	151	0.54
Keep River	G8100263	Feb	98	53			1.0	0.055	143	0.50
Keep River	G8100264	Feb	98	59			<1.0	0.047	105	1.36
Keep River	G8100265	Feb	98	60			<1.0	0.052	103	1.23
Keep River	G8100266	Feb	98	76			<1.0	0.054	65	2.25

Watercourse	Sample Location	Month	Year	Conductivity	pH	Turbidity	Nitrate, NO3	Total Phosphorus	Total Suspended Solids	Total Kjeldahl Nitrogen
Keep River	G8100267	Feb	98	75			<1.0	0.076	202	1.33
Keep River	G8100268	Feb	98	64			2.0	0.086	540	0.36
Keep River	G8100269	Feb	98	50			3.0	0.110	676	0.40
Keep River	G8100270	Feb	98	65			<1.0	0.079	201	1.76
Keep River	G8100271	Feb	98	65			<1.0	0.051	93	1.78
Keep River	G8100272	Mar	98	81	5.6	58	<1.0		85	
Sandy Creek	G8100210	Dec	97							
Sandy Creek	G8100211	Dec	97							
Sandy Creek	G8100212	Dec	97							
Sandy Creek	G8100213	Dec	97							
Sandy Creek	G8100214	Dec	97							
Sandy Creek	G8100215	Dec	97							
Sandy Creek	G8100216	Dec	97							
Sandy Creek	G8100217	Dec	97							
Sandy Creek	G8100218	Dec	97	141			3.5	0.040	15	
Sandy Creek	G8100219	Dec	97	180			6.9	0.031	33	
Sandy Creek	G8100220	Dec	97	173			4.2	0.029	38	
Sandy Creek	G8100221	Dec	97	73			7.1	0.043	85	
Sandy Creek	G8100222	Dec	97	78			<0.2	0.014	14	
Sandy Creek	G8100223	Dec	97	75			<0.2	0.024	46	
Sandy Creek	G8100224	Dec	97	104			<0.2	0.016	16	
Sandy Creek	G8100225	Jan	98	66			3.9	0.039	96	
Sandy Creek	G8100226	Jan	98	118			<0.2	0.015	28	
Sandy Creek	G8100227	Jan	98	118			<0.2	0.011	8	

Table G.5 Water Quality Data from Department of Lands, Planning and Environment 1997–1998 (continued)

Watercourse	Sample Location	Month	Year	Conductivity (µS/cm)	pH	Turbidity (NTU)	Nitrate, NO3 (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)
Sandy Creek	G8100228	Jan	98	119	5.7	11	<0.2	0.014	14	
Sandy Creek	G8100229	Jan	98	95			0.8	0.030	78	
Sandy Creek	G8100230	Jan	98	79			<0.2	0.010	12	
Sandy Creek	G8100231	Jan	98	78			1.3	0.020	68	
Sandy Creek	G8100232	Jan	98	66			<0.2	0.022	60	
Sandy Creek	G8100233	Jan	98	48			0.4	0.029	109	
Sandy Creek	G8100234	Jan	98	36			0.5	0.032	147	
Sandy Creek	G8100235	Jan	98	35			0.6	0.050	202	
Sandy Creek	G8100236	Jan	98	49			0.7	0.050	229	
Sandy Creek	G8100237	Jan	98	34			<0.2	0.037	139	
Sandy Creek	G8100238	Feb	98	39	5.7	11	1.2	0.019	33	
Sandy Creek	G8100239	Mar	98	84			<1.0		70	
Border Ck	G8100106	Dec	97	59			15.7	0.122	3342	
Border Ck	G8100107	Dec	97	33			3.8	0.134	2351	
Border Ck	G8100108	Dec	97	47			3.7	0.110	3351	
Border Ck	G8100109	Dec	97	48			3.3	0.134	3037	
Border Ck	G8100110	Dec	97	38			6.6	0.188	1058	
Border Ck	G8100111	Dec	97	40			4.7	0.226	645	
Border Ck	G8100112	Jan	98	94			2.0	0.072	2580	
Border Ck	G8100113	Jan	98	40			2.1	0.107	2132	
Border Ck	G8100114	Jan	98	24			3.9	0.132	942	0.84
Border Ck	G8100115	Jan	98	56			2.5	0.100	2556	
Border Ck	G8100116	Jan	98	28			3.2	0.115	932	
Border Ck	G8100117	Jan	98	21			1.0	0.113	677	
Border Ck	G8100118	Jan	98	27			1.3	0.111	1369	
Border Ck	G8100119	Jan	98	28			1.4	0.107	1050	
Border Ck	G8100120	Jan	98	42			<0.2	0.088	434	
Border Ck	G8100121	Jan	98	42			<0.2	0.062	191	
Border Ck	G8100122	Jan	98	57			<0.2	0.047	151	
Border Ck	G8100123	Feb	98	57			<0.2	0.050	135	
Border Ck	G8100124	Feb	98	62			1.0	0.110	113	0.85
Border Ck	G8100125	Feb	98	62			<1.0	0.130	99	
Border Ck	G8100126	Feb	98	65			1.0	0.082	107	
Border Ck	G8100127	Feb	98	70			<1.0	0.073	102	
Border Ck	G8100128	Feb	98	69			<1.0	0.081	103	
Border Ck	G8100129	Feb	98	74			10.0	0.190	967	
Border Ck	G8100130	Feb	98	66			1.0	0.210	998	
Border Ck	G8100131	Feb	98	40			<1.0	0.220	2146	1.84
Border Ck	G8100132	Feb	98	35			<1.0	0.088	2081	
Border Ck	G8100133	Feb	98	34			<1.0	0.180	1154	
Border Ck	G8100134	Feb	98	28			<1.0	0.150	489	
Border Ck	G8100135	Feb	98	45			1.0	0.150	205	

Watercourse	Sample Location	Month	Year	Conductivity	pH	Turbidity	Nitrate, NO3	Total Phosphorus	Total Suspended Solids	Total Kjeldahl Nitrogen
Border Ck	G8100136	Feb	98	67			2.0	0.120	221	0.78
Border Ck	G8100137	Feb	98	77			1.0	0.110	173	0.71
Border Ck	G8100138	Feb	98	83			1.0	0.110	141	0.68
Border Ck	G8100139	Feb	98	91			<1.0	0.067	124	0.76
Border Ck	G8100140	Feb	98	47			7.0	0.140	418	1.04
Border Ck	G8100141	Feb	98	91			<1.0	0.130	122	0.63
Border Ck	G8100142	Feb	98	52			2.0	0.100	350	0.52
Border Ck	G8100143	Mar	98	51			3.0	0.180	308	0.90

Table G.6 Water Quality Data from Larson (1999)

River	Month	Year	Conductivity ($\mu\text{S/cm}$)	Temp (Celcius)	pH	Salinity (ppt)
Bucket Spring	October	98	426	27.7		0.2
Bucket Spring	October	98	431	27.7	7.6	0.2
Bucket Spring	October	98	434	28.9	7.6	
Bucket Spring	October	98	475	28.9	7.6	
Alligator Hole	October	98	82	30.6	6.8	0.0
Milligan Lagoon	October	98	82	31.1	7.2	0.0
Augustus Hole	October	98	312	32.7	7.6	0.1
Augustus Hole	October	98	312	30.8	7.6	0.2
Augustus Hole	October	98	333	30.9	7.6	0.2
Augustus Hole	October	98	312	32.7	7.6	0.1
Emerald Spring	October	98	21	32.0	6.4	0.0
Oakes Creek	October	98		35.1		48.8
Oakes Creek	October	98		33.3		47.0
Sandy Creek	October	98	100	32.8	7.2	0.1
Sandy Creek	October	98		30.1		40.5
Sandy Creek	October	98		34.6		45.3
Sandy Creek	October	98		39.0		61.1
Keep River	October	98	163	32.5	7.2	0.1

APPENDIX H

WATER INFILTRATION MODELLING

ORD RIVER IRRIGATION AREA STAGE 2 PROPOSED DEVELOPMENT OF THE M2 AREA

Water Infiltration Modelling for the Ord Sugar Project

P

prepared for:

WESFARMERS LIMITED, MARUBENI CORPORATION

AND

THE WATER CORPORATION OF WESTERN AUSTRALIA

Level 7, 40 The Esplanade

Perth WA 6000

Prepared by:

Kinhill Pty Ltd

ACN 007 660 317

47 Burswood Road, Victoria Park WA 6100

Telephone 08 9362 5900, Facsimile 08 9362 5627

August 1999

Limitations Statement

In preparing this report, Kinhill Pty Ltd has relied upon and presumed accurate certain information (or absence thereof) relative to the site that was obtained from examination of records in the public domain or provided by government officials and authorities. Except as otherwise stated in the report, Kinhill has not attempted to verify the accuracy or completeness of any such information.

The findings, observations and conclusions expressed by Kinhill Pty Ltd in this report are not, and should not be considered, an opinion concerning the feasibility of establishing irrigated agriculture on the site. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon information in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia, and is subject to and issued in connection with the provisions of the agreement with Kinhill Pty Ltd. Kinhill Pty Ltd accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

TABLE OF CONTENTS

1	INTRODUCTION	1
2	MODEL DESCRIPTION	1
3	INPUT DATA	2
3.1	Soil Properties	2
3.1.1	Retentivity	2
3.1.2	Infiltration Rates	4
3.1.3	Sodicity Impact	5
3.1.4	Root Zone Model	5
3.1.5	Root Depth	5
3.2	Rainfall and Evaporation	5
3.3	Evapotranspiration	6
3.4	Irrigation Schedule	6
4	RESULTS	8
5	MODEL OUTPUT	13
5.1	Soil Moisture Levels	13
5.2	Run off	13
5.3	Accession to Groundwater	13
5.4	Irrigation Efficiency	14
5.5	General	14
6	SUMMARY AND CONCLUSIONS	14
7	REFERENCES	15

1 Introduction

Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia are investigating the feasibility of developing approximately 32,000 hectares of land in the East Kimberley region of Western Australia and the Northern Territory, predominately for the irrigated cultivation of sugar cane. As part of these feasibility studies it was necessary to quantify the percolation of rainfall and irrigation water from the surface (unsaturated zone) to underlying groundwater. This was carried out using the numerical water balance model LEACHM (Hutson & Wagnnet 1992) to simulate conditions of best practice irrigation management as proposed for the Project.

The LEACHM model is briefly described in Chapter 2 while Chapter 3 describes the input data used, including the physical properties of the soil profile assumed to be representative of the development area and meteorological conditions. The results are summarised in Chapter 4.

The prediction of effects of project development on the underlying groundwater was the subject of a separate study (Kinhill Pty Ltd 1999).

2 Model Description

The simulation of the water balance within the unsaturated zone of the soil profile was undertaken using the LEACHM (Hutson & Wagnnet, 1992) model. LEACHM is a process-based model of water movement, including uptake by plants, in the unsaturated zone of the soil profile.

The multi-layer model calculates the water balance on a sub-daily basis. The time step is based on the numerical stability of the finite differencing technique employed to numerically evaluate the equations describing water transport in the soil. Typically each day is divided into at least ten time steps.

The following data is required to evaluate the water balance:

- initial moisture content and hydrological constants for calculation of retentivity (i.e. variation of the soil moisture as a function of pore pressure) and hydraulic conductivity for each soil segment;
- rates of irrigation application and rainfall amounts;
- potential daily evaporation;
- crop details including time of planting and harvest, root and crop growth parameters as well as potential limits for water extraction by plants.

3 Input data

3.1 SOIL PROPERTIES

The area proposed for development has cracking clay soils, predominately Cununurra clay and to a lesser extent Aquitaine clay. Cracking clay soils are often described as black soils or vertisols. They exhibit significant shrinking and swelling with changes in moisture content and when dry they often have deep, open desiccation cracks. The permeability of wet or moist cracking clay soils is very low. Aquitaine clays have a higher clay content than Cununurra clay and are therefore generally even less permeable.

3.1.1 Retentivity

A soil profile of Cununurra clay (alkaline phase) was assumed to be representative of the range of soil types that occur in the area proposed for development. The physical properties of this soil profile are given in Table 3.1.

Table 3.1 Physical properties of Cununurra Clay - Alkaline Phase

Depth Range [cm]	Bulk Density [kg/m ³]	Clay content [%]	Moisture at 1/10 atm pore pressure [%]	Moisture at 1/3 atm pore pressure [%]	Moisture at 1 atm pore pressure [%]	Moisture at 15 atm pore pressure [%]
0-15	1.32	57.8	32.45	26.33	25.96	22.72
15-85	1.43	40.6	33.84	31.90	26.38	20.66
85-145	1.40	24.5	34.82	33.20	28.95	22.27
145-205	1.62	28.4	30.23	28.44	23.89	19.11

Source: Dixon 1996

The numerical evaluation of retentivity is required within the LEACHM model. This is achieved by fitting a curve to the data in Table 3.1, extending from fully saturated soil to wilting point (i.e. for pore pressures in a range from 0 atm to 15 atm). Results of this procedure are shown in Figure 3.1.

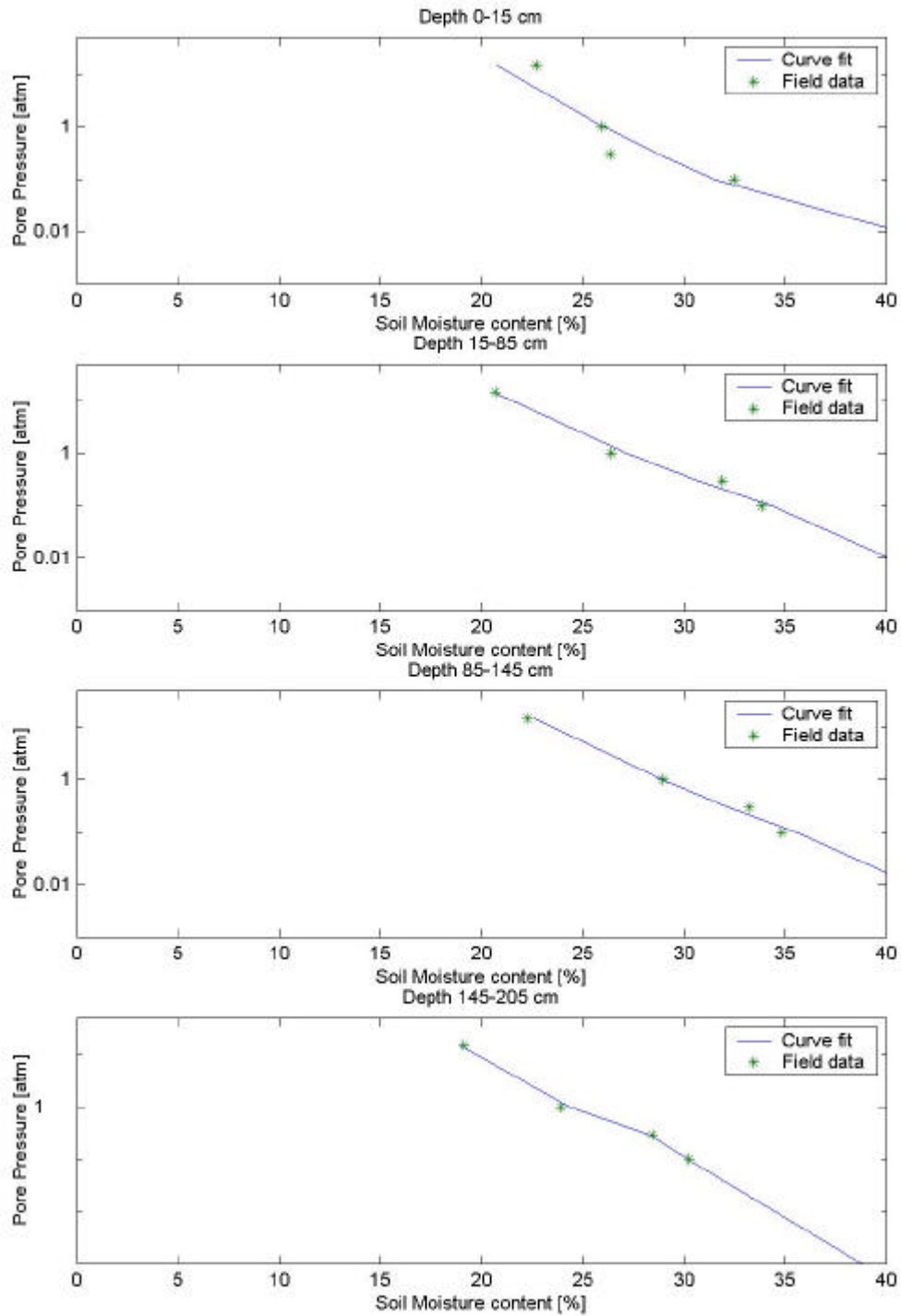


Figure 3.1 Soil retentivity data used in the analysis

3.1.2 Infiltration Rates

Water enters the soil profile readily when it is dry and cracked, but after swelling has occurred and the cracks have closed up the entry of water is restricted (Muchow and Wood 1981). Cultivation and furrow and bed forming practices also modify the behaviour of the surface layer under irrigation. The moisture content of the Cununurra clay under irrigated crops does not vary significantly below depths of around 1.6 m (Muchow and Wood 1981 and others) indicating that this is the limit of the shrinkage and swelling.

Measurement of the saturated hydraulic conductivities of Cununurra clay soils is difficult and only long-term tests lasting over at least several days are considered accurate (R Shaw and A Peck personal communication). The only long term infiltration tests on Cununurra clays are those carried out by Banyard (1983) who investigated channel and drain seepage rates. Ponding tests were carried out on ten 50 m long sections of the irrigation channels on the Ivanhoe Plain over a period of 7 to 13 days. Infiltration rates ranging from 10 mm to 47 mm per day were recorded for channels in the Cununurra clay. These channels had been excavated to depths of 1 to 2 m and water was ponded in them to depths of 0.3 m to 1.0 m. The arithmetic mean of the infiltration rates was 20 mm per day and the median value was 18 mm per day.

Muchow and Wood 1981 investigated infiltration rates for Cununurra clay under furrow irrigation of Kenaf with irrigation applications on 6 day and 12 day intervals. This investigation used flow meters to measure the input and output flows in 160 m long furrows. Irrigation was shut off when the lateral wetting of the bed between the furrows was complete. This generally occurred after 5 to 6 hours. Infiltration rates over this short period averaged 250–300 mm per day but decreased slightly to 180 mm per day by the time irrigation was shut off. Soil moisture readings to a depth of 1.85 m were made immediately before each irrigation and again two days after irrigation as shown in Figure 3.2. Their results show that:

- there was little change in moisture contents below a depth of 1.0 m;
- the major change in moisture content was in the top 300 mm where the moisture content went from wilt point (20%) to saturation (45%) with irrigation.

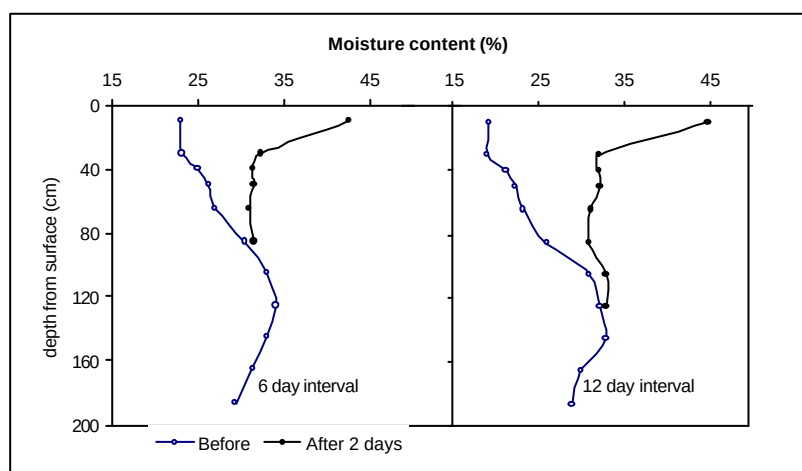


Figure 3.2 Volumetric moisture profiles immediately before, and two days after irrigation (Muchow and Wood 1981).

3.1.3 Sodicity Impact

Cununurra and Aquitaine clays are sodic at depth with Exchangeable sodium percentage (ESP) as high as 27 in the virgin state. Irrigation with Ord River water, which has a bicarbonate content of 110 mg/L, increases ESP in the rootzone (especially at the bottom) through precipitation of calcium carbonate (Lavalle 1983). The ESP levels can be managed by varying the leaching factor (George 1983 and Lavalle 1983).

A target ESP of 15 at a depth of 1.3–1.5 m has been set for this project. Elevated ESP levels reduce the hydraulic conductivity of the soil and Queensland experience (Shaw and Yule 1978) indicates that at an ESP of 15 the infiltration rate of a cracking clay would be reduced from 20 mm/day to 3 to 5 mm/day.

3.1.4 Root Zone Model

The LEACHM model replicates sprinkler or flood irrigation practices where the whole surface is wet evenly. However, in common with other models of this type, it does not replicate furrow irrigation systems where water can soak sideways from the furrow into the dry soil bed on which the crop is established. Water intake in this dry area is not dependent upon saturated hydraulic conductivity, but rather on the sorptivity of the soil.

A reasonable approximation of the surface conditions and the infiltration rates down the profile were achieved in LEACHM by using:

- a 0.3 m surface layer with hydraulic conductivities in the range of 180 mm–300 mm/day and a mean of 240 mm/day;
- a layer for the balance of the root zone down to 1.5 m with a hydraulic conductivity between 10 mm and 47 mm/day and a mean of 20 mm/day;
- a layer of sodicity affected soil below the bottom of the root zone from 1.5 m to 2.2 m with a hydraulic conductivity between 3 mm–5 mm/day.

Below 2.2 m the clay content of the soil decreases and the hydraulic conductivity increases rapidly. Water passing below this depth therefore has easy access to the underlying groundwater.

3.1.5 Root Depth

The model allows for roots to penetrate to 1.3 m with root density decreasing with depth. The water uptake weighting factors established for cracking clay soils at Emerald (Shaw and Yule 1978) were used.

3.2 RAINFALL AND EVAPORATION

The year 1991 (Figure 3.3) was selected following a review of rainfall and pan evaporation data as representing typical meteorological conditions for the development area. This approach is preferred to using average figures because it allows the actual evaporation occurring during rainfall events to be used. The high

winds associated with some storms cause quite high evaporation to occur during wet periods.

Half hourly rainfall data from the Bureau of Meteorology was used which allowed run-off to be modelled with considerable more accuracy than when daily rainfall data is used. Effective Rainfall was calculated by reducing actual rainfall by 10% to approximate interception of rainfall by the sugar cane.

3.3 EVAPOTRANSPIRATION

The scenario modelled is for a mature sugar cane crop which has a crop factor of 0.85 (Holden 1998) except during the harvest and regrowth period. Cane will be harvested throughout the dry season but in this simulation a harvest at the end of July is assumed. The last irrigation occurs on the June 30th to allow the soil to dry out for harvest and resumes in mid August following re-establishment of the furrows after harvest.

The crop factor used for the bare soil plus young cane is 0.5 in late August, 0.6 in September and 0.8 in October. The LEACHM model does not have provision for variable crop factors and these were therefore simulated by reducing the pan evaporation rate.

3.4 IRRIGATION SCHEDULE

Irrigation water was assumed to be applied after an estimated soil moisture deficit of 75 mm, based on pan evaporation, crop factor and effective rainfall. A simplified irrigation schedule without tailwater return was also assumed, such that each irrigation applied 100 mm of water to allow for an in field irrigation efficiency of approximately 75%. In Queensland infield irrigation efficiencies of 71-73% with furrow lengths of 400–1,200 m can be achieved (Holden 1998), hence the 75% factor is consistent with best practice conditions that would be adopted for the project. It is noted that whole farm irrigation efficiency would be approximately 85% with tailwater recycling as proposed for this project. The irrigation schedule adopted by the model is shown in Figure 3.3.

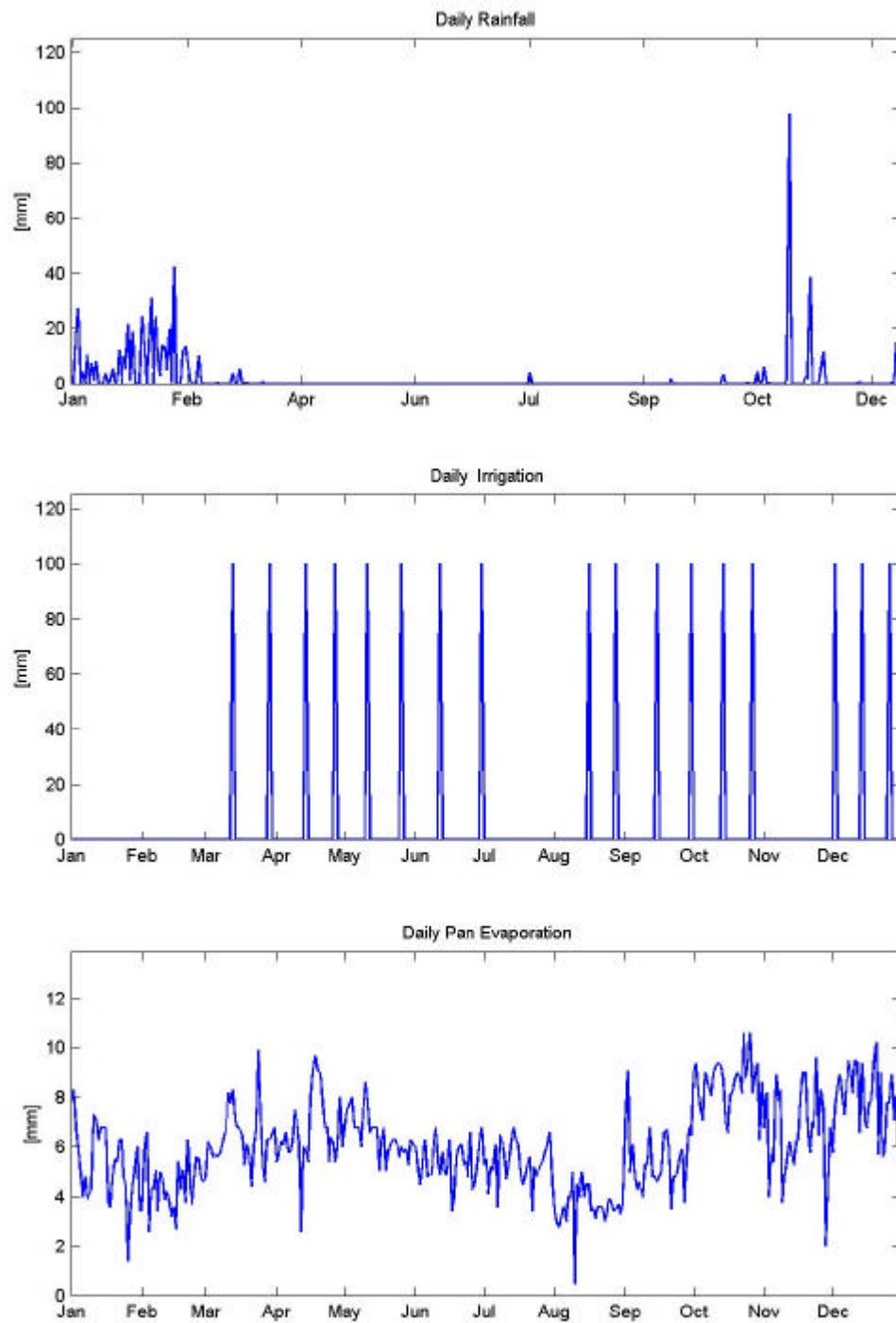


Figure 3.3 Meteorological data from 1991 and irrigation schedule used in the analysis

4 Results

Simulations were undertaken for a range of saturated hydraulic conductivities for each of the three layers of the soil profile used in the model. The investigated alternatives are summarised in Table 4.1.

Table 4.1 Summary of investigated alternatives

Case No.	Hydraulic conductivity within top 300 mm [mm/day]	Hydraulic conductivity at depths 300 – 1500 mm [mm/day]	Hydraulic conductivity at depths 1500 – 2200 mm [mm/day]
1	180	10	3
2	180	47	3
3	180	10	5
4	180	47	5
5	300	10	3
6	300	47	3
7	300	10	5
8	300	47	5
9	240	20	4

Note that Case 9 represents mid values for the range of values investigated for each of the three soil layers.

Relevant water balance parameters derived by the model for typical (mid range) soil properties (Case 9) are shown as daily values in Figure 4.1, cumulative daily values in Figure 4.2 and monthly values in Figure 4.3. These parameters include infiltration of rainfall and irrigation water into the topsoil, evapotranspiration, excess water on the surface which runs off the field and drainage (accessions) to groundwater. Figure 4.4 gives a summary of the main components of the water balance, including the temporal evolution of the soil moisture profile over depth.

The predicted annual accessions to groundwater for all the investigated alternatives are shown in Table 4.2.

Table 4.2 Predicted annual accessions to groundwater for investigated alternatives

Case No.	Accessions to groundwater [mm/year]
1	56
2	84
3	63
4	93
5	68
6	107
7	75
8	119
9	94

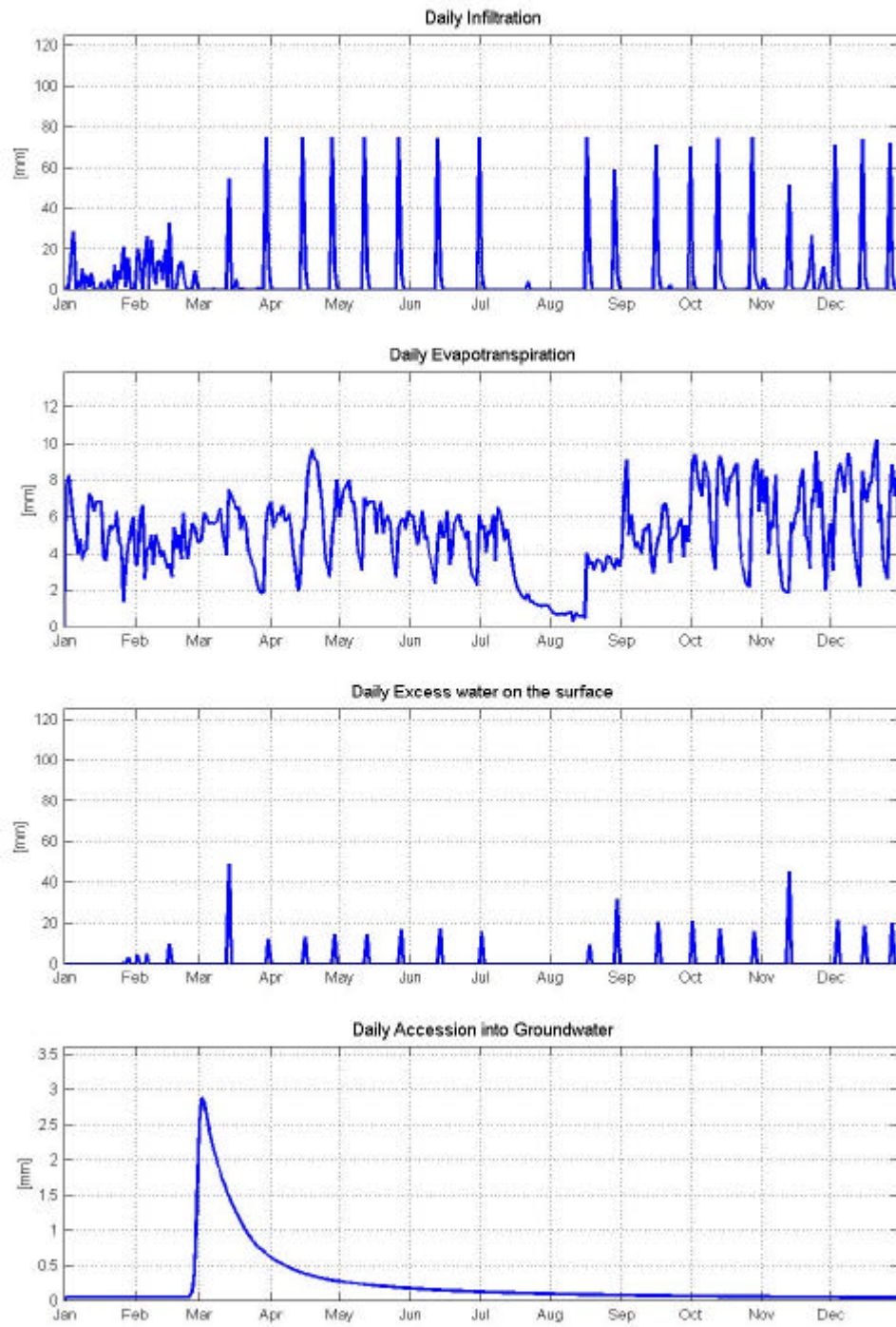


Figure 4.1 Soil water balance – daily basis for Case 9

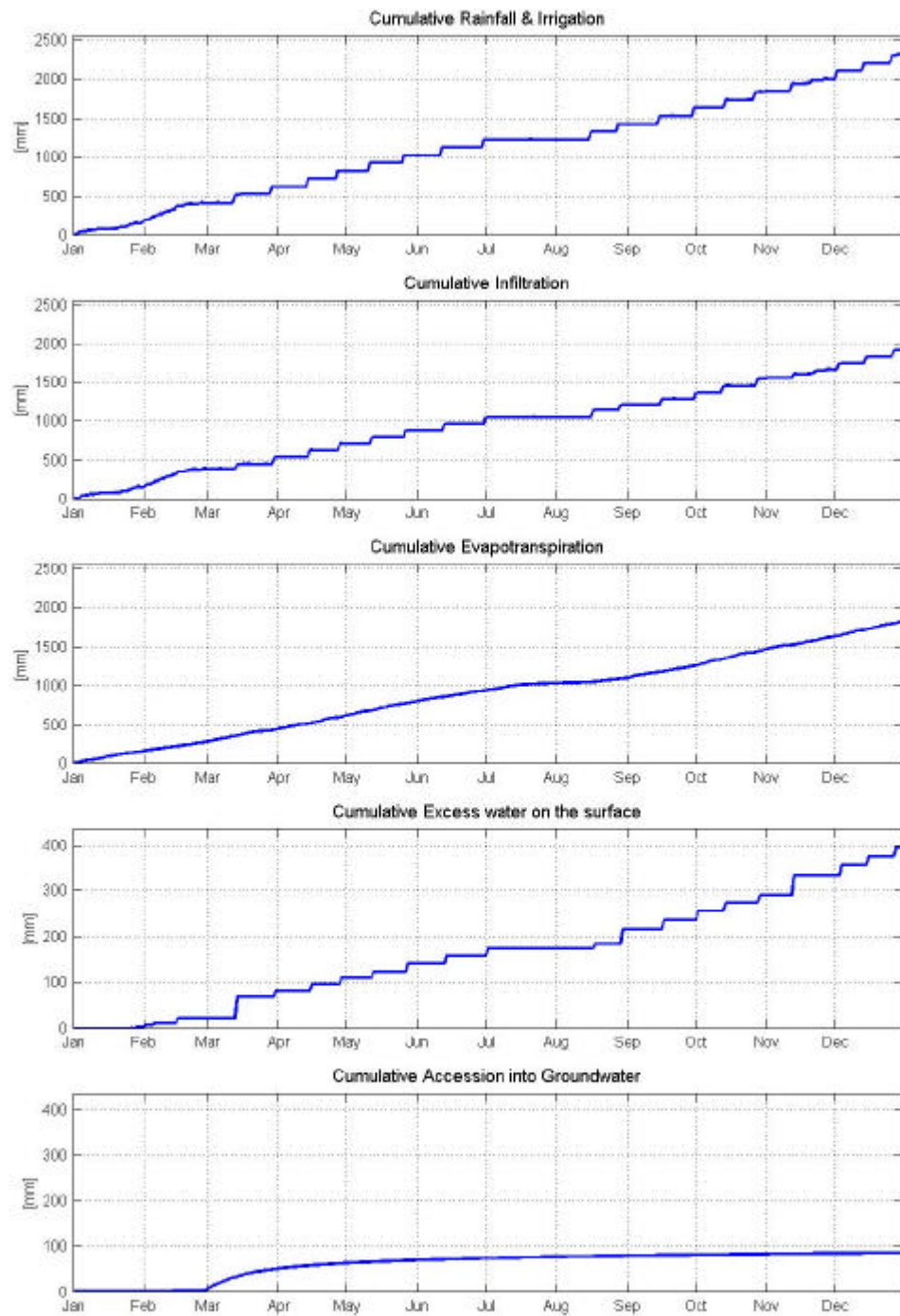


Figure 4.2 Soil water balance - cumulative daily basis for Case 9

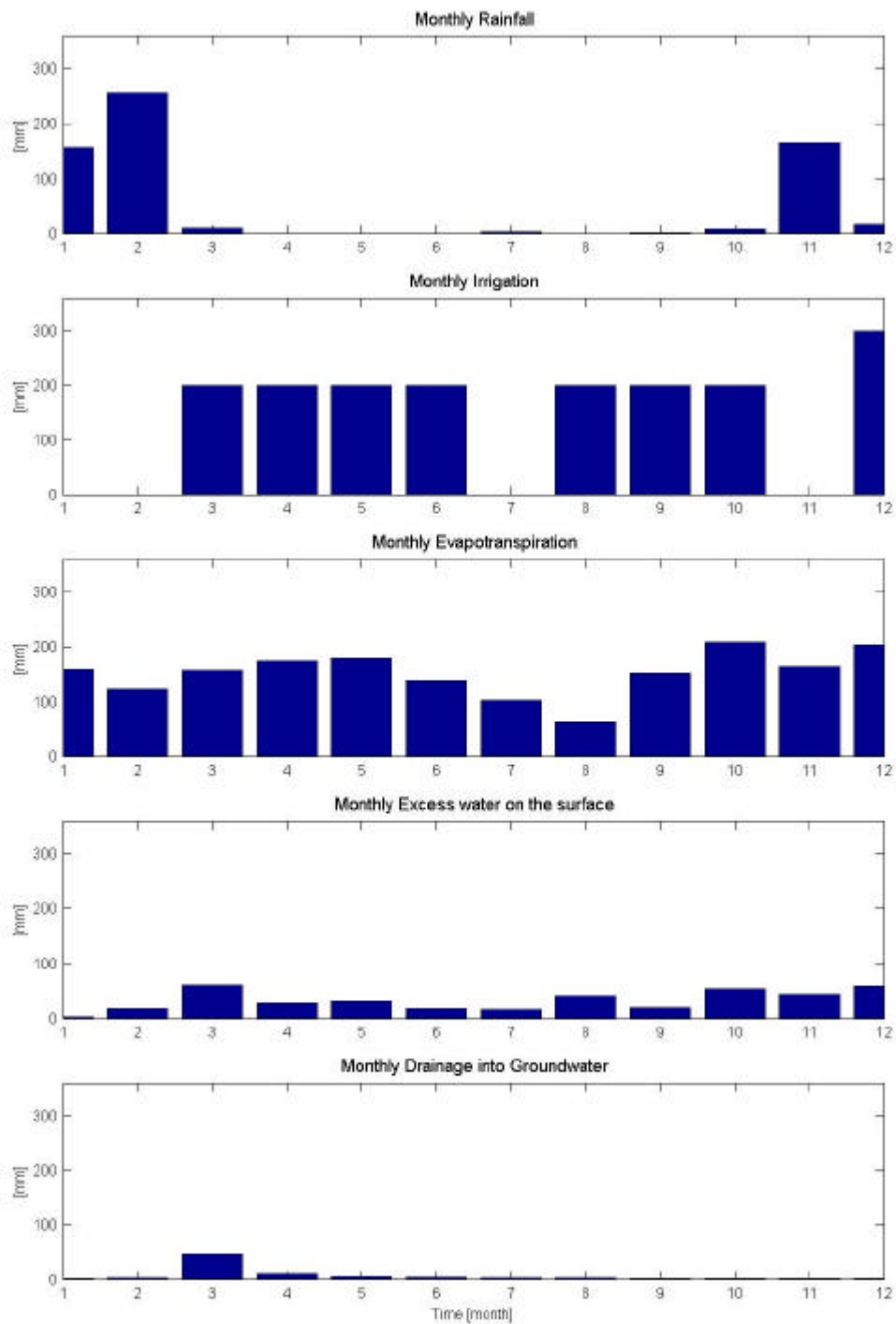


Figure 4.3 Soil water balance - monthly data for Case 9

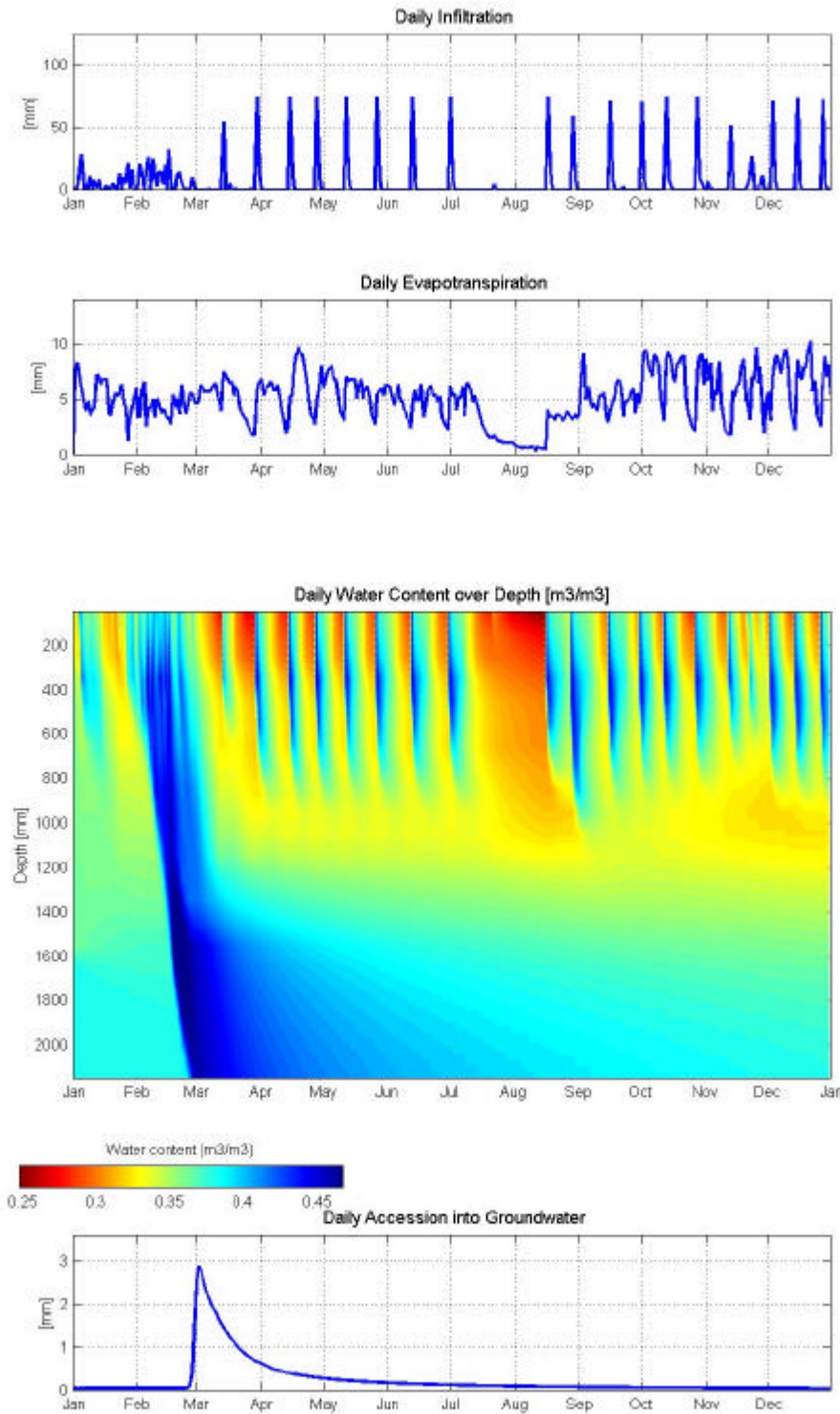


Figure 4.4 Summary of the soil water balance for Case 9

5 Model Output

The model has used a range of soil hydraulic conductivities to estimate the likely range of infiltration rates to groundwater. The following observations are made on the results of Case 9 which uses mid range values for each layer of the soil profile.

5.1 SOIL MOISTURE LEVELS

The soil moisture contents which develop during a typical year are shown graphically in Figure 4.4. These moisture contents demonstrate a reasonable fit with the results of Muchow and Wood 1983 in that:

- The moisture content at a depth of 1.0 m remains constant and at field capacity throughout the irrigation season.
- The shallow part of the root zone approaches saturation for the first few days after each irrigation.

5.2 RUN OFF

The model predicts annual run off from the fields to the tailwater return systems of 400 mm. Approximately 200 mm occurs between April 1 and October 31, when virtually no rain occurred (Figure 4.3). During this period 1,200 mm of irrigation water was applied and run off was therefore approximately 17%.

During the remaining five months rainfall was 678 mm. The model estimates that 68 mm was intercepted (used by the crop) and 200 mm or 32% ran off.

The 20% run-off for irrigation and 32% for rainfall are within the range estimated by (George 1983) from twelve years of gauging record on Drain D2B in Stage One of the Ord River Irrigation Area.

5.3 ACCESSION TO GROUNDWATER

The model predicts that almost all of the accession to groundwater will occur as the result of rainfall in the wet season (Figure 4.4). This is in conformity with studies of other irrigation areas in Australia which show that the main source of infiltration to the groundwater is rainfall. This factor results from the soil profile at the end of the dry season no longer being dry but at field capacity due to irrigation.

The model estimates that 1,900 mm of rainfall and irrigation will infiltrate into the soil (Figure 4.2). The predicted 94 mm/a of infiltration therefore represents a leaching factor of 0.05. This leaching factor is within the range of 0.04–0.07 estimated from furrow irrigated sugar cane in Stage One of the Ord River Irrigation Area using data from the studies by George 1983.

If in practice it is necessary to reduce the accession rate then stopping irrigation ahead of the wet season and allowing the sugar cane to dry out the profile should be the most effective strategy.

5.4 IRRIGATION EFFICIENCY

Of the 1,200 mm of irrigation water applied through the April to October period when no rain occurred, approximately 200 mm was predicted to run-off and 30 mm was predicted to pass into the groundwater. This result is consistent with best practice irrigation management as it indicates an irrigation efficiency of 80% which is at the upper end of the achievable infield irrigation efficiency (J.H. Sherrad, Department of Agriculture, Kununurra pers. comm., 1998).

5.5 GENERAL

The soil properties in the development area vary significantly with location. Therefore the model described in this paper can only be an approximation of the average conditions. However, the model results provide confidence that reasonable irrigation regimes can be designed for a range of soil properties that will contain accessions to groundwater within the range predicted for average conditions.

The use of in field soil moisture probes, which is now common in the vineyard industry in Western Australia, should allow irrigation scheduling with considerable accuracy.

6 Summary and Conclusions

Numerical simulations have been undertaken to evaluate the likely range of accession rates to groundwater that would result from the proposed Ord Sugar Project. The simulations were based on a range of soil data and average meteorological conditions.

The predicted soil moisture values and other parameters which result from using a reasonable irrigation regime are in accordance with the data observed on the Kimberley Research Station and in Stage One of the Ord River Irrigation Area.

For average soil properties and meteorological conditions the LEACHM model predicts an average accession rate to groundwater of 94 mm/a. Simulations for a wide range of soil properties results in predictions of annual accessions to groundwater as low as 56 mm/a or as high as 119 mm/a.

7 References

- Banyard, R. 1983, Ord Irrigation Area Ivanhoe Plain Waterway Infiltration. Public Works Department Water Resources Branch Report No. WRB57.
- Dixon, J. 1996, Soils of the Weaber plain, East Kimberley, WA. Natural Resources Assessment Group Agriculture Western Australia. Resource Management Technical Report No 152.
- George P. R. 1983 unpublished, Soil Salinity and Sodicity in Relation to Land Use. Ivanhoe Plain Ord River Project Area. Department of Agriculture.
- Holden J.R, (ed) 1998, Irrigation of Sugarcane. Bureau of Sugar Experiment Stations. Queensland.
- Hutson, J. L. and Wegenet, R. J. 1992, LEACHM - Leaching Estimation and Chemistry Model - Version 3, New York State College of Agriculture and Life Sciences, Cornell University, Ithaca, New York, USA.
- Kinhill Pty Ltd 1999, Ord Sugar Project Groundwater Report. Prepared for Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia.
- Lavalle, A. M. 1983, Review of Land and Water Resources of Ord River Irrigation Area Western Australia. Report prepared for Booker Agriculture International.
- Muchow, R. C. and Wood, I. M. 1981, Pattern of Infiltration With Furrow Irrigation and Evapotranspiration of Kenaf (*Hibiscus cannabinus*) Grown on Cununurra Clay in the Ord Irrigation Area. *Aust. J. Exp. Agric. Anim. Husb.* 21, 101-8.
- Shaw. R.J and Yule, D.F. 1978, Assessment of soils for irrigation, Emerald, Queensland, Agriculture Chemistry Branch Technical Report No. 13, Department of Primary Industries, Queensland.

APPENDIX I

GROUNDWATER REPORT

ORD RIVER IRRIGATION AREA STAGE 2 PROPOSED DEVELOPMENT OF THE M2 AREA

Groundwater Report

Prepared for:

**WESFARMERS LIMITED,
MARUBENI CORPORATION AND THE WATER
CORPORATION OF WESTERN AUSTRALIA**
Level 7, 40 The Esplanade
Perth WA 6000

Prepared by:

Kinhill Pty Ltd
ACN 007 660 317
47 Burswood Road, Victoria Park WA 6100
Telephone 08 9362 5900, Facsimile 08 9362 5627

August 1999

Limitations Statement

In preparing this report, Kinhill Pty Ltd has relied upon and presumed accurate certain information (or absence thereof) relative to the site that was obtained from examination of records in the public domain or provided by government officials and authorities. Except as otherwise stated in the report, Kinhill has not attempted to verify the accuracy or completeness of any such information.

The findings, observations and conclusions expressed by Kinhill Pty Ltd in this report are not, and should not be considered, an opinion concerning the feasibility of establishing irrigated agriculture on the site. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon information in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia, and is subject to and issued in connection with the provisions of the agreement with Kinhill Pty Ltd. Kinhill Pty Ltd accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

CONTENTS

Section	Page
1 INTRODUCTION	
2 CLIMATE	
3 HYDROGEOLOGY	
3.1 Basement Geology	6
3.2 Alluvial Sediments	7
3.3 Groundwater Flow	8
3.4 Groundwater Quality	9
4 GROUNDWATER MODELLING	
4.1 Model Development	11
4.2 Sensitivity Analysis	13
4.3 Model Results	13
5 POTENTIAL IMPACTS ON GROUNDWATER QUALITY	
5.1 Quality of Accessions to Groundwater	19
5.2 Weaber Plain	19
5.3 Knox Creek Plain	20
5.4 Keep River Plain	20
6 CONCLUSIONS AND RECOMMENDATIONS	
7 REFERENCES	

ATTACHMENTS

- A Sub-surface geology throughout the project area
- B Model Conductivity Distribution
- C Groundwater Levels - 50mm/yr Accession Rate without Pumping
- D Groundwater Levels - 50mm/yr Accession Rate with Pumping
- E Groundwater Levels - 100mm/yr Accession Rate without Pumping
- F Groundwater Levels - 100mm/yr Accession Rate with Pumping
- G Groundwater Levels - 150mm/yr Accession Rate with Pumping

1 Introduction

This investigation and report was commissioned by Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia to assess the likely impacts of irrigated broad acre farming predominately of sugar cane upon the groundwater environment within the Project Area. The Project Area is located in the east-Kimberley region of Western Australia and adjoining areas of the Northern Territory and comprises portions of the Weaber Plain, Keep River Plain and Knox Creek Plain.

The hydrogeology of the Project Area has been extensively investigated by the Water & Rivers Commission (WA) and the Department of Lands, Planning and Environment (NT). These agencies provided hydrogeological data that enabled Kinhill Pty Ltd to establish a numerical computer model of the Project Area. This model was used to predict changes to the groundwater environment of the Project Area for a range of groundwater management scenarios.

2 Climate

The East-Kimberley region has a tropical monsoonal climate with the wet season extending from December through March contributing largely to the annual average rainfall of 788mm at Kununurra. Net evaporation is high during the summer months, and ranges from 330mm/month in October to 175mm/month in February. The mean maximum monthly temperature is 38.9°C in November and the mean minimum monthly temperature is 14.1°C in July. The relative humidity ranges from a low of 32% in July to 65% in January.

3 Hydrogeology

The geology of the East-Kimberley region has been described by Moray and Beere (1988). Geological descriptions of portions of the Project Area are presented in Laws (1991), Sweet, et al, 1974, and Whitehead and Fahey, 1985.

3.1 BASEMENT GEOLOGY

3.1.1 Weaber Plain

The Weaber Plain is bounded by outcropping basement rock to the north (Weaber Range) and south (Pinicombe Range and Sorby Hills). In the south-west, the Plain is bounded by basement rock with the exception of the Cave Spring Gap region.

Underlying most of the Weaber Plain is a mixture of Precambrian to Permian units of varying lithology, including sandstone, limestone, shale and conglomerate. Through Cave Spring Gap, the basement rocks consist of Precambrian sandstone and shale of the Bastion Group. A major basement inlier within the plain, Folly Rock, is composed of Proterozoic sandstones of the Carr-Boyd Group. North of Folly Rock, the basement changes to being Carboniferous Milligans Formation shale.

In general, Paleozoic sediments underlie the alluvial sequence through the northern Weaber Plain. In the south of the plain, the basement is a thin sequence of Devonian limestone and sandstone overlying Cambrian Antrim Plateau Volcanics. The Sorby Hills range comprises a sequence of complexly folded and faulted Carboniferous sandstone and limestone.

3.1.2 Knox Creek Plain

The geological strike along the Knox Creek Plain is dominantly north-south, consistent with the major axis of the plain. To the west and north, the basement units underlying the plain include the Carboniferous Burt Range Formation, Septimus Limestone and well-bedded limestone and sandstone of the Devonian-Carboniferous Button Beds. Other units of the Landfield Group may be present. The plain is largely underlain by the Milligans Formation shale, incised by a paleochannel and locally overlain by calcrete. To the east, the plain is underlain by undifferentiated Permo-Carboniferous sandstone. Knox Creek does not incise into the basement beneath the plain, except for an area of limited extent in the north of the plain. The creek is generally fully contained within the alluvial sediments.

3.1.3 Keep River Plain

The basement rock underlying the Keep Plain region is for the most part undifferentiated Permo-Carboniferous sandstone. Carboniferous shale is found underlying the plain

immediately east and southeast of the Spirit Hill Homestead. The alluvial sediments have incised into and been deposited upon both of these units.

3.2 ALLUVIAL SEDIMENTS

3.2.1 Weaber Plain

Alluvial sediments comprise the upper 5 to 35m of the Weaber Plain (Nixon, 1997b, 1997e). These sediments are presumed to have been deposited by a paleochannel of the Ord River, when it is postulated to have flowed to the north-east beneath the Weaber Plain and then roughly along the course of the present day Keep River. The sequence of sediments is one of a basal coarse-grained unit deposited by the main river channel. These paleochannel sediments are restricted in extent to a narrow valley through the plain and are of considerable importance to the hydrogeology. The extent and nature of the paleochannel sediments are discussed in a later section. Across the entire plain the alluvial sequence becomes progressively finer upwards with varying thickness. Little is known in detail of the variability of these sediments as the drilling which has been undertaken to date is sparse compared to the area being considered and there is little correlation between bore holes for coarser or finer units (Nixon 1997a, 1997b, 1997d, 1997e).

3.2.2 Knox Creek Plain

The alluvial deposition within the Knox Creek Plain differs in part from that in the Weaber Plain by the poorer definition of the paleochannel (although the paleochannel is continuous beneath the eastern side of the plain) and the finer nature of the sediments. The alluvial sediments in the paleochannel become progressively deeper and broader in the northern part of the Plain. A fining upward sequence is postulated, with the basal part of the sequence being finer than the Weaber Plain.

Calcrete is found beneath the western Knox Creek Plain overlying the paleochannel sediments or directly upon the basement complex. The calcrete varies greatly in width and thickness, to as much as 4km wide and 15m thick.

3.2.3 Keep River Plain

It has been postulated that the ancient course of the Ord River passed through the Weaber Plain and into the Keep River Plain, and that the river incised a deep channel which was subsequently in-filled with Tertiary and Quaternary sediments. In the west, the paleochannel is up to 35m deep with a coarse basal unit approximately 10m thick. This is the downstream continuation of the paleochannel as described for the Weaber Plain. Above the coarse paleochannel sediments is a finer sequence with clayey sand at base, fining upwards to a silty clay near surface. Drilling by the Northern Territory Government has delineated the paleochannel extent and thickness (Humphreys et al, 1995).

3.3 GROUNDWATER FLOW

3.3.1 Weaber Plain

The general flow gradient across the Weaber Plain is from the west to the east. Elevated groundwater levels exist in the Cave Spring Gap, as a result of existing irrigation activities. The groundwater elevation just outside of the current irrigation area is around 22 to 26m AHD, which is around 5m below ground surface. From here groundwater flow is through the Cave Spring Gap and under the Weaber Plain. The elevation of the water table decreases to be between 5 and 10m AHD in the vicinity of Folly Rock. This is some 20m below surface, but may be up to 35m below ground in some areas. In the north of the plain, near Point Spring, the groundwater elevation is higher than on the central part of the plain.

A groundwater elevation at around 17m AHD has been recorded (Nixon 1997a, 1997e) and it is postulated that the broad areas of sandy soils in the Border Creek region (north of the Weaber Plain) contribute some recharge to the sediments underlying the plain. This is also an area of relatively shallow bedrock, which may contribute to the higher groundwater elevations. The water table associated with Point Spring occurs within the bedrock system and is entirely separated from the alluvial sediments.

East of Folly Rock, the groundwater elevation is at around 5m AHD and remains above 3m AHD to the eastern end of the plain. This is approximately 15–20m below the general level of the plain. The incised valley of the Keep River is at approximately 12–14m AHD, approximately 10m above the groundwater level. There is no evidence of groundwater interaction with the river in this area, although data are poor. Groundwater recharge across the plain is considered to be very low. The existing groundwater gradient appears to be largely controlled by the paleochannel throughflow from the Ivanhoe Plain and by recharge from the Border Creek area.

In the southern part of the plain, near Sorby Hills, extensive drilling for mining exploration has shown the basement rocks to be limestone and dolomite, which have significant groundwater storage potential. It is presumed that there is little if any upward movement of groundwater from the basement rocks into the alluvial sequence, and that it is more likely that groundwater in this area will move from the alluvial sediments into the bedrock.

3.3.2 Knox Creek Plain

Groundwater flow beneath the Knox Creek Plain appears to be to the north, following the paleochannel beneath the eastern portion of the plain. In the southern part of the Knox Creek Plain the groundwater elevations in the region and south of Milligan Lagoon are approximately 8 m higher than those in the northern part of the plain. Groundwater flow in the southern section is to the north-west, from the Northern Territory section to Western Australia. In the north of the plain the groundwater levels range from around 7m AHD down to 3–4m AHD where the Knox Creek Plain joins the Weaber Plain. This is approximately 10–15m below the ground surface.

Recent drilling undertaken on behalf of Wesfarmers Limited, Marubeni Corporation and the Water Authority of Western Australia has shown that Milligan Lagoon is the surface expression of a local perched water table. The base of the perched aquifer is a clay layer that occurs to a depth of up to at least 9m below the surface. The regional water table is some

20m below the level of the lagoon. The lagoon is fed by rainfall and runoff and, possibly, minor groundwater inflow from the adjacent hills to the west.

The sediments of Knox Creek and its tributaries are not considered to be currently part of the groundwater system as the bed level of these creeks is some 10m above the current groundwater level. However, it is likely that these creeks, due to the general sandy nature of their bed profiles are important groundwater recharge features during the wet season. Recharge from the rest of the plain is considered to be minimal.

3.3.3 Keep River Plain

Groundwater flow beneath the Keep River Plain is a continuation of the flow coming from the west in the Weaber Plain. Groundwater elevations in the west of the Keep River Plain are at or around the level of those in the Weaber Plain. Groundwater flow is generally to the north east, along the line of the plain, with a smaller component to the north west, from the higher Permo-Carboniferous outcrop area towards the alluvium.

The Keep River and Sandy Creek are in connection with the alluvial sediments along their length and where these are tidal or semi-tidal, they provide a natural tidal control on groundwater levels. Beneath the Keep River Plain the basement rocks are in part Permo-Carboniferous sandstone which is highly permeable and contains good quality groundwater. In the eastern end of the plain it appears that the permeable Permo-Carboniferous sandstone and the incised paleochannel sediments comprise a single hydraulic unit. However, the nature, extent and degree of connection between the two systems have yet to be confirmed.

3.4 GROUNDWATER QUALITY

3.4.1 Weaber Plain

Groundwater quality in the Weaber Plain is generally fresh to slightly brackish (Nixon 1997a, 1997b, 1997e). In the Cave Spring Gap groundwater salinity is around 1,000mg/L TDS (Nixon, 1997d) and it is not clear if the salinity of groundwater in this area is influenced by current irrigation or is the result of an older recharge signature. Throughout the southern and central parts of the Weaber Plain, groundwater salinity ranges from 70mg/L to 2,600mg/L. In the northern edge of the plain the groundwater salinity areas appear to be associated with bedrock highs, however, water analyses from Point Spring (Nixon, 1997e) indicate that the groundwater emanating from bedrock in that region is of good quality (50mg/L).

3.4.2 Knox Creek Plain

Groundwater salinity ranges from 60 to 20,800mg/L TDS but in general is around 1,000mg/L. The groundwater is a sodium chloride type with elevated sulphate and bicarbonate. Based on airborne electromagnetic studies conducted jointly by Western Australia and Northern Territory Governments, there is considered to be a significant difference in the groundwater quality in the west of the plain compared to the east, reflecting the nature of the bedrock. Where alluvial sediments overlie the Milligan Formation shale the groundwater appears to be more saline than the groundwater overlying the Permian-

Carboniferous Sandstone. Delineation of the contact between these units and the potential impact on groundwater quality is discussed in Chin et al, 1997.

3.4.3 Keep River Plain

Groundwater salinity varies greatly, between 100 and 51,000 mg/L, across the Keep River Plain (Humphreys et al, 1995). The Department of Lands Planning and Environment have identified six main salinity zones, based on airborne electromagnetic surveys and inferred basement geology. From the west to east across the plain, the groundwater salinity changes from moderate to high (1,000 to 20,000mg/L), through a low salinity region (salinity expected to be less than 2,000mg/L) and then into a more saline region which is within the influence of the tidal reaches of Sandy Creek. The groundwater chemistry is dominated by sodium chloride ions, although bicarbonate concentrations are also commonly high. Nitrate levels are generally below 1–2mg/L.

4 Groundwater modelling

4.1 MODEL DEVELOPMENT

A numerical groundwater model was used to simulate the response of the groundwater environment to irrigation activities on the surface. The model used was MODFLOW (McDonald and Harbaugh, 1984), an internationally recognised code-verified finite difference groundwater model. Model set-up and pre- and post-processing were carried out using the Visual MODFLOW package (Guiguer and Franz, 1996).

The hydrogeological data used to construct the model were obtained from the Water and Rivers Commission (WA) and the Department of Land Planning and Environment (NT). In particular, these agencies jointly compiled a series of sub-surface cross-sections of the geology throughout the area of interest (Attachment A). These sections comprised the basis for the geometry of the model.

All of the scenarios modelled assumed that all of the black soil areas within the perimeter infrastructure would be used for irrigated agriculture. Subsequently, Project planning has included some of these black soil areas in conservation areas, particularly north west of Folly Rock on the Weaber Plain and on the eastern Keep River Plain. The area north west of Folly Rock was shown by the modelling to be prone to rapid groundwater level rises if used for irrigation. Therefore, use of a portion of this area for conservation would partially mitigate these effects predicted by the MODFLOW model for this area.

4.1.1 Model Parameters

The entire Project Area was included in a single continuous model. The model comprised 198 columns and 207 rows having individual cell dimensions of 250 metres by 250 metres. The hydrogeology was simplified into three layers:

- *Layer 1* comprises sandy silty sediments beneath the surface black soil and was assigned a uniform hydraulic conductivity of 5 m/day in accordance with the observations of Nixon (1997c) who suggested an expected range in conductivity between 1 m/day and 10 m/day. This layer was assigned a specific yield of 10%.
- *Layer 2* was assigned two hydraulic conductivity values in order to simulate the paleochannel aquifer. In the Weaber Plain-Keep River Plain area, a central line of cells was assigned a hydraulic conductivity of 100 m/day with the flanking area assigned 25 m/day. In the Knox Creek Plain, the central line was assigned a value of 35 m/day with the flanking area 10 m/day. This approach was adopted to simulate the zones of relatively high permeability known to occur with the paleochannel aquifer. All paleochannel units were assigned a specific yield of 15%. The remainder of the active

cells in the layer were assigned hydraulic conductivity and specific yield values equivalent to those for the basement complex (layer 3).

- *Layer 3* comprised the basement complex of varying lithology and was assigned a hydraulic conductivity of 0.5 m/day and a specific yield of 5%, with the exception of the Keep River Plain where the underlying Permo-Carboniferous Sandstone aquifer was simulated with a hydraulic conductivity of 10 m/day and a specific yield of 10%.

The spatial distribution of hydraulic conductivity values for each layer are supplied in Attachment B.

‘No-flow cells’ were assigned to areas flanking the Project Area, generally at a distance of about 3km from the nearest proposed development. This action imposes a degree of conservatism as the model does not allow for dissipation of groundwater into these cells.

The northern boundary was set as a ‘General Head Boundary’ having a fixed head of 0m AHD (mean sea level). Keep River and Sandy Creek were assigned as ‘River Cells’ for the reaches under permanent water. The ephemeral reaches of the Keep River and Sandy Creek and Knox Creek were defined as ‘Drain Cells’.

The southern-western boundary at Cave Springs Gap was also a ‘General Head Boundary’ having a fixed head of 22m AHD.

The rate assigned to infiltration (accession rate) of irrigation water to groundwater is a critical parameter of the model. The likely accession rate of irrigation water and rainfall from the irrigation area for the irrigation practices proposed for the Project was determined to be 94mm/a by modelling of the unsaturated zone using the LEACHM numerical model (as described in Kinhill Pty Ltd 1999). The groundwater model was therefore run at a rate of 100mm/a as the base case, as well as for a variety of accessions ranging up to 150mm/a.

Additional infiltration was simulated from the irrigation water distribution channels and the balancing storage dams. The infiltration rate assumed for this infrastructure was the design criterion of 2mm/day.

The USGS MODFLOW model was used as a design tool as well as for predicting groundwater response for the proposed groundwater management strategy. All of the modelling scenarios assumed a period of fifty years to represent long-term operation of the Project. This period reflects a sensible limit on the use of the available data and the accuracy of the modelling based upon these data.

Sustainability of the irrigation practices over a period longer than the 50 years time horizon used in the modelling was assumed to be demonstrated if the rate of groundwater change at 50 years was shown by the modelling to be small and within the accuracy normally expected of groundwater modelling. This situation was achieved for the base case (100mm/a infiltration rate) by running the model with progressively more dewatering bores and then optimising the time for commencement of pumping and the pumping rate.

Other accession rates that were modelled (50 mm/a and 150 mm/a) utilised the same bore layout and number as that developed for the base case. However, the pumping rate and time of commencement of pumping were different to that used for the base case.

It is noted that none of the modelling scenarios included the effects of field drains that may be used as a groundwater management measure in the future.

Field drains consist of a series of perforated pipes laid below the surface that would allow the entry and collection of groundwater, however, they are only effective when groundwater levels are at or above the level at which the drains are laid.

The omission of field drains was a deliberate action as the model was used to identify the extent of the cropped area that is likely to require this form of management. The result of omitting the field drains from the modelling scenarios is that the model would overstate the rate of groundwater rise, particularly when groundwater levels are within 2 m of the surface.

4.2 SENSITIVITY ANALYSIS

The model was run with various parameters to determine those which would have the most impact upon the model predictions. The parameters examined included hydraulic conductivity, variations in the ratio of vertical to horizontal hydraulic conductivity, specific yield, accession rates and river conductance.

The groundwater accession rate was seen to be the most critical parameter. This parameter controls the actual volume of water entering into the groundwater regime either as increased storage (rising water table) or increased discharge (subsurface outflow or discharge into surface streams).

The 'River Conductance' is a parameter that simulates the efficiency of the riverbeds as an infiltration surface to both recharge the aquifer (where river stage is above groundwater heads) or to drain the aquifer (where aquifer heads exceed river stage). 'River Conductance' is an important control on the predicted response of the water table for those areas immediately flanking the river nodes. This parameter cannot be directly measured by field testing as it is a relationship of the riverbed hydraulic conductivity, bed thickness and river geometry. The model was run using 'River Conductance' derived by calculation and those derived by trial and error by the Water and Rivers Commission and Department of Lands Planning and Environment in their attempt to pseudo-calibrate previous Ord River Irrigation Area groundwater models.

Variations of the aquifer parameters hydraulic conductivity and specific yield affect the ability of the aquifer(s) to dissipate hydraulic head and store the infiltrating irrigation waters. However, the effects are not pronounced in comparison to the regional effects of the accession rate and the local effects of the river.

4.3 MODEL RESULTS

The results from the modelling of a variety of scenarios are described in the following sections. The scenarios include a range of accession rates from the areas proposed for irrigation, and coupled with/without groundwater control via pumping from dewatering bores.

4.3.1 50mm/a Accession Rate without Pumping

The LEACHM infiltration modelling indicated that an accession rate of approximately 50mm/a would be the lowest likely accession rate from the irrigated farmland.

Figure C-1 shows the time predicted for groundwater levels to reach within 5m of ground level while figure C-2 shows the groundwater levels predicted for simulation periods of 10, 20, 40 and 50 years—in all cases there is no use of dewatering bores.

In this scenario, groundwater levels are predicted to remain below 5m beneath most of the eastern Weaber Plain, eastern Knox Creek Plain and the Keep River Plain for the 50-year simulation period. Furthermore, the area north-west of Folly Rock is predicted to experience groundwater levels within 5m of ground level by year 20. The areas of high water levels are predicted to expand with time to surround Folly Rock. An area of waterlogging (defined herein as groundwater levels within 1m of ground level) is predicted north-west of Folly Rock by year 50.

A low-lying area in the north-east of the plain, adjacent to Border Creek, is predicted to encounter water levels within 5m of ground level by year 30. However, these rises would be partially suppressed by the draining effect of Border Creek as the water table reached the bed level of the creek.

The balancing storage dam on the Weaber Plain is predicted to create a groundwater mound with groundwater levels within 5m of the ground surface by year 10. The area of high water level is predicted to expand with time and waterlogging beneath the balancing storage dam would begin by year 20.

The eastern Keep River Plain has relatively shallow water levels and these are predicted to remain within 5m of ground level throughout the 50 year simulation period. The high water levels predicted in the northern Keep River Plain, in particular the short time shown to reach within 5 m (Figure C-1) are a result of the low ground elevation, the high initial hydraulic head adopted for the model and the constant head boundary set at mean sea level. The sub-surface discharge into Sandy Creek attenuates the water level increases in this area.

The western Knox Creek Plain, where underlain by relatively shallow basement rock, has initial depths to groundwater between 15m and 20m. Under the scenario modelled, the water table is predicted to rise to within 5m of ground level by year 50.

The predicted groundwater discharges to the major watercourses are shown in Table 4.1.

Table 4.1 Predicted groundwater discharges to watercourses, 50 mm/a accession rate without pumping

Year	Knox Creek Discharge (ML/a)	Keep River Discharge* (ML/a)	Sandy Creek Discharge* (ML/a)
10	0	4,550	375
20	0	5,072	347
30	0	5,628	361
40	73	6,148	382
50	174	6,579	402

* includes sub-aqueous discharge into permanent tidal reaches

4.3.2 50mm/a Accession Rate with Pumping

The 50mm/a accession rate was also modelled in conjunction with a series of dewatering bores located within the paleochannels. The effectiveness of pumping to control rising water levels has been investigated by the Water and Rivers Commission and described by O'Boy

(1997, 1998). Figure D-1 presents the time predicted for water levels to reach to within 5m of the ground surface while figure D-2 shows the predicted depth to groundwater for simulation periods of 10, 20, 40 and 50 years.

The model indicated that with a groundwater pumping rate of 12,045ML/a, waterlogging could be avoided over the whole of the proposed irrigation area for the entire simulation period.

Relatively high water levels (within 5m of ground level) are predicted beneath and adjacent to the balancing storage dam on the Weaber Plain within 10 years. The north-western Weaber Plain is predicted to encounter water levels within 5m of groundwater level by year 30. The predicted high water levels in the north-western Weaber Plain are due to the initial shallow water table and the presence of shallow and relatively impermeable basement rocks. The area of high water level associated with the balancing storage dam and the north-western Weaber Plain is predicted to expand laterally with time.

Groundwater levels beneath the Keep River Plain are not predicted to change markedly over time due to the sub-surface groundwater discharge effected through the Keep River and Sandy Creek.

The Weaber Plain, south of Folly Rock and south of the paleochannel, is predicted to experience significant rise in water levels but at 50 years the water table is predicted to still be below 5m from ground level. The western Knox Creek Plain similarly shows groundwater mounding but the water table remains below 5m from ground level for the entire 50-year simulation period.

Comparison of the groundwater levels after 40 and 50 years shown in Figure D2 shows that little or no change is predicted over this time period. These results would indicate that groundwater management would be sustainable for a much longer period than the 50 year period adopted for the modelling.

The predicted groundwater discharges to the major watercourses are shown in Table 4.2.

Table 4.2 Predicted groundwater discharges to water courses, 50 mm/a accession rate with pumping rate of 12,045ML/a

Year	Knox Creek Discharge (ML/a)	Keep River Discharge* (ML/a)	Sandy Creek Discharge* (ML/a)
10	0	4,550	375
20	0	4,675	255
30	0	4,741	204
40	0	4,784	184
50	0	4,813	177

** includes sub-aqueous discharge into permanent tidal reaches*

Initially, the pumping discharges from most bores would be of suitable quality to re-introduce into the irrigation cycle. At some locations and over time, the salinity may become unsuitable to be used for irrigation and disposal pipelines to the estuarine environment may be required.

4.3.3 100mm/a Accession Rate without Pumping

The LEACHM infiltration modelling indicated that 94mm/a is the likely average rate of groundwater accession from the irrigation area. For the MODFLOW analysis this rate was rounded up to 100mm/a.

Figure E-1 presents the time predicted in years for water levels to reach within 5 m of ground level, while figures E-2 shows the depth to groundwater for simulation periods of 10, 20, 40 and 50 years—in all cases there is no use of dewatering bores.

Under this scenario, the model indicates that groundwater levels would rise to 5 m of ground level within 5 years in a small area of the Weaber Plain northwest of Folly Rock and within 20 years this area may experience waterlogging. Furthermore, the western Weaber Plain in general is predicted to experience problems with rising water levels within 20 to 30 years. This result is due to the relatively shallow depth to basement and the absence of a paleochannel to assist subsurface drainage of this region.

The western Knox Creek Plain, underlain by shallow basement that were assumed to be impermeable, is predicted to experience water levels within 5 m of the surface within 20 years, and to become waterlogged by year 50.

The Keep River Plain has a relatively shallow water table in the natural state and water levels are predicted to remain high under irrigation. The proximity of the Keep River and Sandy Creek would serve to regulate the water levels and prevent waterlogging.

As for the 50mm/a accession rate scenarios, high water levels are also predicted in the area surrounding the balancing storage dam on the Weaber Plain.

The predicted groundwater discharges to the major watercourses are shown in Table 4.3.

Table 4.3 Predicted groundwater discharges to water courses, 100 mm/a accession rate without pumping

Year	Knox Creek Discharge (ML/a)	Keep River Discharge* (ML/a)	Sandy Creek Discharge* (ML/a)
10	0	7,044	1,118
20	39	8,515	1,288
30	226	9,689	1,427
40	430	10,749	1,535
50	689	11,977	1,615

** includes sub-aqueous discharge into permanent tidal reaches*

4.3.4 100mm/a Accession Rate with Pumping

MODFLOW was utilised to analyse the consequences of a 100mm/a accession rate with groundwater control using dewatering bores installed into the paleochannels with a pumping rate of 12,045ML/a from the dewatering bores.

Regional rises in the water table are still predicted, although the rate and magnitude of water level increases are markedly attenuated, in comparison to the same accession rate without pumping, over most of the Project Area. Figure F-1 presents the time predicted for the water table to reach within 5 m of ground level and figure F-2 shows the predicted depth to groundwater for simulation periods of 10, 20, 40 and 50 years.

Water levels as predicted to remain greater than 5m from ground level over the whole of the Keep River Plain, the eastern Weaber Plain, and the eastern Knox Creek Plain for the entire 50-year simulation.

Higher water levels are predicted in areas not underlain by, or immediately adjacent to, the paleochannels. The western Weaber Plain and western Knox Creek Plain are predicted to begin to experience water levels within 5m of ground level by 5 and 30 years, respectively. Waterlogging is considered possible in some areas of the western Weaber Plain by year 30, and in the western Knox Creek Plain by year 50. The area adjacent to the balancing storage dam on the Weaber Plain is predicted to have water levels within 5 m of ground level by year 10 and local waterlogging by year 30.

The western Knox Creek Plain is underlain by Devonian limestone. These rocks have been hydraulically tested as part of the Sorby Hills mineral project investigations. The limestone comprises a significant aquifer where local conditions have resulted in solution-enhanced secondary permeability. The secondary permeability is likely to be restricted to zones of structural discontinuities such as faults and fractures. Because of the general north-south structural trend, it is possible that permeable zones could be located within the limestone basement beneath the western Knox and be pumped to reduce the groundwater rise in this area. This additional pumping was not modelled due to the unpredictable nature of the spatial distribution of the basement permeability and the uncertainty that pumping from the basement would lower shallow water levels.

Comparison of the groundwater levels after 40 and 50 years shown in Figure F2 show only minor changes over this period, with the changes mainly restricted to the western Weaber Plain and western Knox Creek Plain. These results would indicate that the groundwater management would be sustainable for a much longer period than the 50 year period adopted for the modelling, particularly if groundwater management is augmented by use of field drains in the areas of higher groundwater levels.

The predicted groundwater discharges to the major watercourses are shown in Table 4.4.

Table 4.4 Predicted groundwater discharges to water courses, 100 mm/a accession rate with pumping rate of 2,045ML/a

Year	Knox Creek Discharge (ML/a)	Keep River Discharge* (ML/a)	Sandy Creek Discharge* (ML/a)
10	0	7,044	1,118
20	0	8,116	1,134
30	25	8,847	1,168
40	61	9,361	1,205
50	96	9,768	1,236

** includes sub-aqueous discharge into permanent tidal reaches*

Initially, the pumping discharges from most dewatering bores would be of suitable quality to re-introduce into the irrigation cycle. At some locations and with increasing time, the salinity may become unsuitable to be used in the irrigation, and disposal pipelines would be required.

4.3.5 150mm/a Accession Rate with Pumping

A scenario using an accession rate of 150 mm/a was modelled in order to ascertain the behaviour of the groundwater system to an accession rate well above the range anticipated for the Project. Because the previous 100mm/a runs indicated the necessity for active groundwater control at higher accessions, the 150mm/a case was only run with pumping, at a rate of 20,440ML/a from the same bore layout developed for the 100 mm/a scenario. Figure G-1 presents the contours of time for water levels to rise within 5m of the surface while figure G-2 presents the water levels at simulation periods of 10, 20, 40 and 50 years.

In the western Weaber Plain, water levels within 5m of ground level are predicted by year 10, including an area of waterlogging northwest of Folly Rock. The predicted area of high water level expands with time to comprise a significant portion of the Weaber Plain by year 40 and the area of waterlogging is predicted to encompass the western Weaber portion of the Plain by year 50.

In the western Knox Creek Plain, high water levels are predicted by year 20, rising to create waterlogging conditions by year 30. The areas of high water levels and waterlogging are predicted to expand to comprise most of the Knox Creek Plain by year 50.

The Keep River Plain water levels are predicted to remain relatively constant throughout the 50-year simulation. The area of high water levels in the eastern Keep River Plain is predicted to expand slightly with time but no area of waterlogging is predicted to develop. Water levels beneath the upper Keep River Plain are predicted to rise from 10 to 15m below surface to 5 to 10m below surface.

As for the simulations of lower accession rates, high water levels are predicted beneath and adjacent to the balancing storage dam on the Weaber Plain.

Overall, the modelling results would indicate that groundwater management would not be sustainable at the assumed pumping rate for much over 40 years without extensive reliance on field drains. Groundwater pumping from additional bores would be possible and this may extend the sustainable period of groundwater management, however, this scenario was not modelled.

The predicted groundwater discharges to the major watercourses are shown in Table 4.5.

Table 4.5 Predicted groundwater discharges to water courses, 150 mm/a accession rate with pumping rate of 20,440ML/a

Year	Knox Creek Discharge (ML/a)	Keep River Discharge* (ML/a)	Sandy Creek Discharge* (ML/a)
10	0	6,814	1,508
20	0	7,864	1,665
30	0	8,693	1,780
40	63	9,342	1,863
50	265	9,849	1,923

* includes sub-aqueous discharge into permanent tidal reaches

5 Potential impacts on groundwater quality

5.1 QUALITY OF ACCESSIONS TO GROUNDWATER

The groundwater recharge from the irrigation area and the infrastructure would gradually alter the existing groundwater chemistry towards that of the accessions to groundwater.

The irrigation water from the Ord River Irrigation scheme has a salinity of approximately 160mg/L TDS, over half of which is bicarbonate. The effect of evapotranspiration by crops would be to increase the concentration of the dissolved salts, with the level of concentration dependent upon the accession rate.

The soils of the Project Area are generally alkaline and under these conditions a significant proportion of the bicarbonate ions would be expected to precipitate from solution as their concentration increases. However, if it is assumed that the salt ions behave in a conservative manner (i.e. remain in a solution and not precipitate onto the soil) during the process of evapotranspiration, the salinity of accession water from the irrigated area, at an accession rate of 50mm/a, would be approximately 6,000mg/L TDS. For the reasons outlined above, this estimate should represent the upper limit of concentrations of dissolved salts in the accession water. Dilution of the accession water from irrigated areas would occur due to the accessions from the irrigation infrastructure, which would infiltrate at a salinity of approximately 160mg/L TDS. Based on the abovementioned assumptions, the net salinity of all infiltrating waters would be approximately 3,800mg/L TDS for the 50mm/a accession rate. When calculated on a similar basis, and with an accession rate of 100mm/a, the net salinity of the accession water would be approximately 1,900mg/L TDS. It follows that the greater the accession rate from the irrigation areas the lower the salinity of the infiltrating waters.

It is anticipated that local variations would occur as a result of downward flushing of the existing soil salts, which would tend to increase the net salinity of the accession water. With time, the contribution of soil salts would diminish as the salts are flushed and the net salinity would approach the calculated values.

5.2 WEABER PLAIN

The groundwater salinity of the Weaber Plain is fresh to brackish. In the western portion of Weaber Plain the salinity is around 1,000mg/L TDS (Nixon, 1997e). Throughout the southern and central parts of the Plain, groundwater salinity ranges from 70mg/L to 2,600mg/L. At an accession rate of 100mm/a the salinity of the groundwater accessions would be approximately 1,900mg/L TDS. This level is within the range of groundwater salinity beneath the Weaber Plain. Therefore, no significant impacts are expected.

5.3 KNOX CREEK PLAIN

The groundwater salinity of the Knox Creek Plain ranges 60mg/L to 13,000mg/L TDS, but in general is around 1,000mg/L (Nixon, 1997a). The higher salinity levels are generally found associated with the shale basement complex where downward flushing is inhibited. At an accession rate of 100mm/a the predicted accession water salinity quality is within the existing range of groundwater salinity and no significant impacts are expected.

5.4 KEEP RIVER PLAIN

The groundwater salinity beneath the Keep River Plain is more variable than for the other plains, ranging from approximately 100mg/L to 51,000mg/L TDS. The higher salinity is likely to be influenced by the proximity of the tidal Keep River and Sandy Creek which are hydraulically connected to the groundwater regime. The predicted salinity of the accession water is lower than the salinity of the existing groundwater beneath much of the lower Keep River Plain and within the general range for the remaining Keep River Plain. In the lower Keep River Plain, it is possible that soil salts may contribute significantly to the net salinity of the accession water in the early years of irrigation, thereby raising the salinity of accessions to salinity levels of existing saline groundwater. No significant impacts are therefore predicted for water quality beneath the Keep River Plain.

6 Conclusions and recommendations

The results of the MODFLOW analysis indicate that broadacre flood irrigation farming would lead to rises in the groundwater levels beneath the irrigated areas. This would be expected of any irrigation development. However, the results also indicate the rate and magnitude of rising water levels could be managed effectively through the utilisation of dewatering bores.

Groundwater levels beneath the irrigated areas underlain by the paleochannel aquifer could be suppressed sufficiently by pumping to prevent unacceptably high levels for the 50 year simulation period for all scenarios except an accession rate of equal to or greater than 150mm/a. The model has indicated that total pumping of the order of 20ML/a is possible from the paleochannel system using the assigned average hydraulic parameters.

The predicted high water levels in the western Knox Creek Plain could be controlled by pumping from the shallow calcrete and/or the Devonian limestone basement rock. A programme of geophysics, exploratory drilling and test pumping would be required to confirm the existence of suitable permeability in this area. This form of groundwater control was not included in the scenarios modelled.

Other areas of high water tables, such as the northwestern Weaber Plain may require use of field drains by year 20. If suitable permeability is not found within the calcrete and limestone basement beneath the western Knox Creek Plain, field drains may also be required in this area by year 40. Groundwater control using field drains was not included in the scenarios modelled.

The groundwater assessment and numerical modelling has indicated that:

- Irrigation should be sustainable for well over 50 years in the Project Area provided that average accession rates from irrigated areas are within the range predicted by the LEACHM modelling (up to 100mm/a) and that suitable groundwater control measures are undertaken;
- The most effective and suitable groundwater control would be by pumping from dewatering bores installed into the paleochannel aquifer;
- Additional groundwater control may be required using field drains in areas not adequately dewatered by bores such as north-west of Folly Rock on the Weaber Plain and the western portion of the Knox Creek Plain;
- In the long-term, groundwater quality would be modified towards that of the infiltrating water after concentration of salts by evapotranspiration;
- Groundwater discharge to the rivers would increase, particularly to the tidal portions of Keep River and Sandy Creek; and

- Groundwater monitoring would be required to adequately assess and manage the local impacts.

Following from these conclusions, it is recommended that:

- several dewatering bores in each of the three plains be installed and tested in the early stages of project development. This would require a programme of geophysics and test drilling;
- The possibility of pumping from the calcrete and/or limestone basement beneath the western Knox Creek Plain should be investigated;
- Transects of monitor bores should be installed adjacent to the Keep River and Sandy Creek to provide data to better understand the interaction between groundwater levels and groundwater discharge to these watercourses. Monitor bores should also be installed in the vicinity of Milligan Lagoon;
- Monitoring bores should be installed throughout the irrigation areas to observe water level trends within individual farm blocks;
- For those areas underlain by the paleochannel or other suitable aquifer, dewatering bores should be installed before water levels are within 5m of the ground level; and
- For those areas where potential waterlogging has been identified, the suitability of field drains should be investigated and confirmed or alternative water control measures demonstrated and adopted.

7 References

- Chin, D., Humphreys, G. and Jolly, P., 1997, Sub-surface Hydrology of the Knox Plain (NT Portion), Department of Lands, Planning and Environment, Water Resources Division, Darwin.
- Gordon, I. and Gardner, T., 1997, Prediction of Deep Drainage for Irrigated Soil Profiles in the Ord River Area, Western Australia, Resources Centre, Queensland Department of Natural Resources, Indooroopilly.
- Guiguer, N. and Franz, T., 1996, Visual MODFLOW, Version 2.11, Waterloo Hydrogeologic Inc., Ontario
- Humphreys, G., Tickell, S., Yin Foo, D. and Jolly, P., 1995, Sub-surface Hydrology of the Keep River Plains, Technical Report No 24/95D, Water Resources Division, Power and Water Authority, Darwin.
- Kinhill Pty Ltd, 1999, Water Infiltration Modelling for the Ord Sugar Project. Report prepared for Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia.
- Laws, A.T., 1991, The Hydrogeology of the Ord River irrigation Area, in conference proceedings "50 Years of Ord Irrigation - Review And Future Perspectives", Kununurra 1991: Western Australia, Minister for North West, Agriculture, Water Resources, Ord Development Council
- McDonald, M.G. and Harbaugh, A.W., 1984, A Modular Three Dimensional Finite Difference Groundwater Flow Model, US Department of the Interior, US Geological Survey, National Center, Reston, Virginia.
- Moray, A.J. and Beere, G.M., 1988, Geology of the Onshore Bonaparte and Ord Basin in Western Australia, Western Australia Geological Survey, Bulletin 134.
- Nixon, R.D., 1997a, Ord River Irrigation Area Drilling Project, Bore Completion Report on the Knox Creek Plain, Water and Rivers Commission Hydrogeology Report No 65.
- Nixon, R.D., 1997b, Ord River Irrigation Area Drilling Project, Bore Completion Report on the Weaber Plain, Water and Rivers Commission Hydrogeology Report 66.
- Nixon, R.D., 1997c, Ord River Irrigation Area Drilling Project, Bore Completion Report on the Ivanhoe Plain, Water and Rivers Commission Hydrogeology Report 70.
- Nixon, R.D., 1997d, , Ord River Irrigation Area Miscellaneous Data Report on the Weaber on Knox Creek Plains, Water and Rivers Commission Hydrogeology Report 72.

Nixon, R.D., 1997e, Ord River Irrigation Area Drilling Project, Bore Completion Report on the Cave Spring Gap, Water and Rivers Commission Hydrogeology Report No 71.

O'Boy, C.A., 1997, Ord River Irrigation Area Test Pumping, Water and Rivers Commission Hydrogeology Report No 48/1997.

O'Boy, C.A., 1998, Ord River Irrigation Area Long-term Test Pumping, Water and Rivers Commission Hydrogeology Report No 125/1998

Sweet, I.P., Mendrum, J.R., Bultitude, R.J. and Morgan, C.M., 1974, The Geology of the Southern Victoria River Region, Northern Territory, Australia, Report 167, Bureau of Mineral Resources.

Whitehead, B.R. and Fahey, G.M., 1985, Geology of the Keep River National Park, Report 1, Northern Territory Geological Survey.

Attachment A

**SUB-SURFACE GEOLOGY
THROUGHOUT THE PROJECT AREA**

[A1 Map to be inserted here]

Attachment B

**MODEL CONDUCTIVITY
DISTRIBUTION**

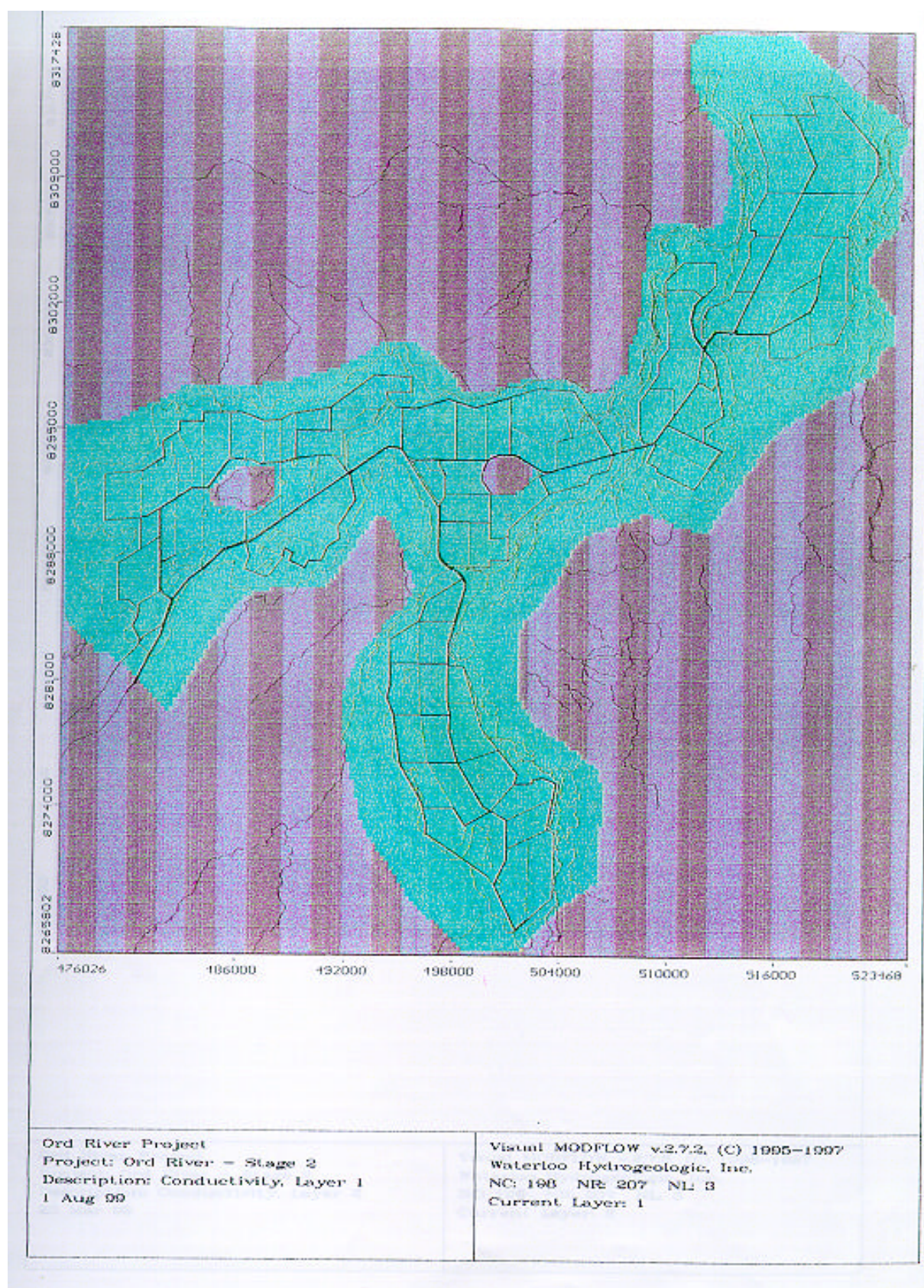


Figure B1 Model conductivity distribution - Layer 1

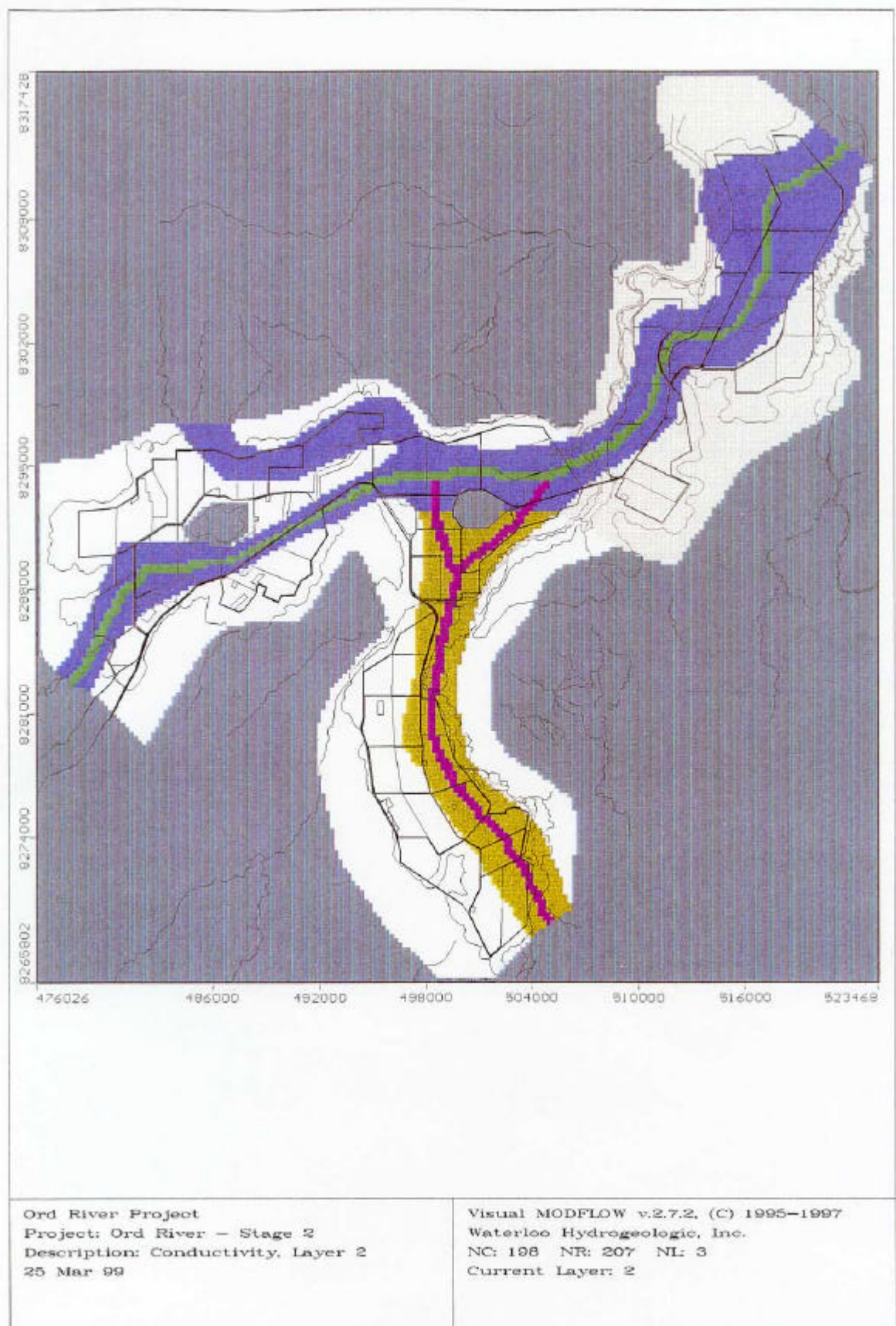
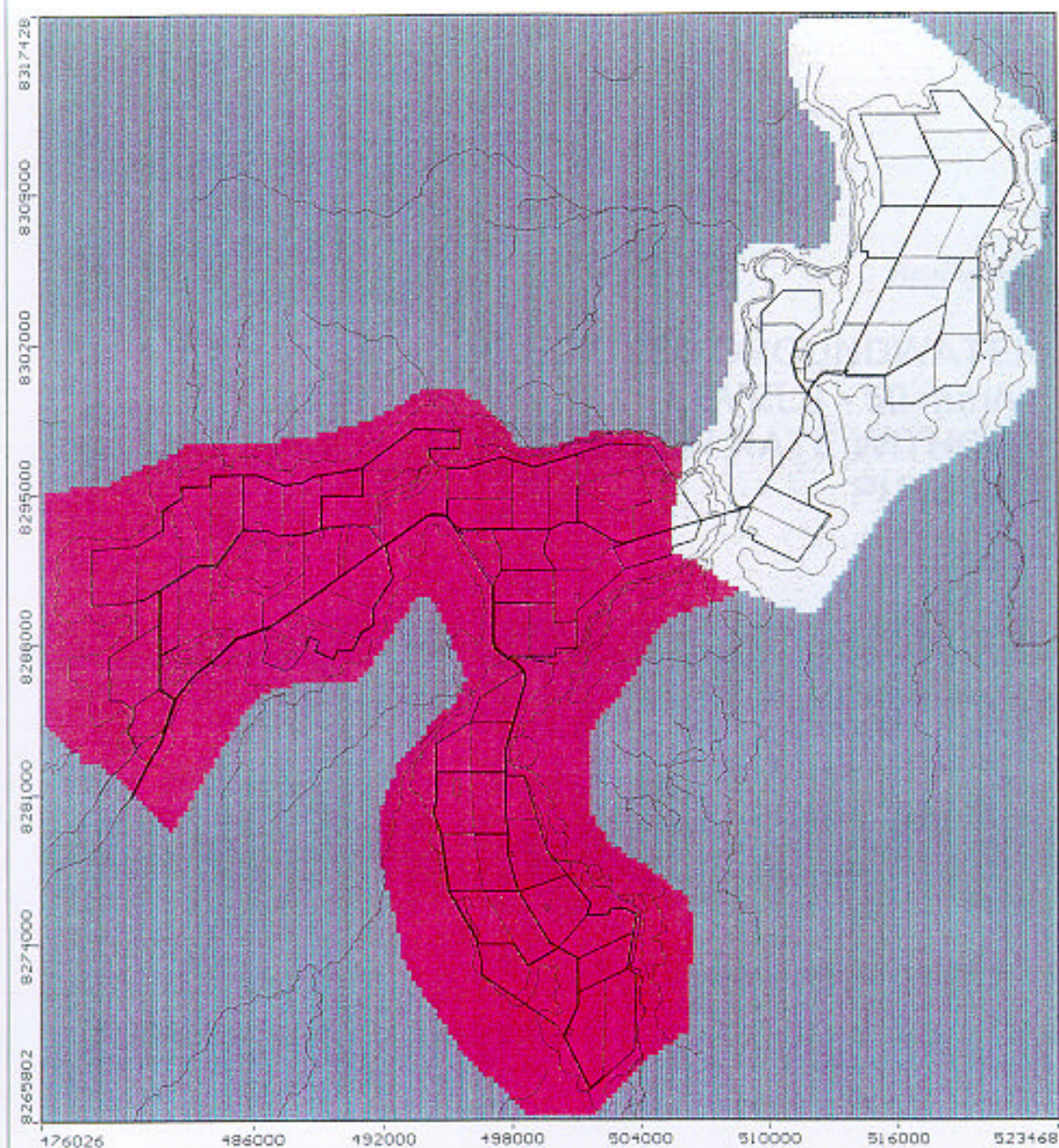


Figure B2 Model conductivity distribution – Layer 2



Ord River Project
 Project: Ord River - Stage 2
 Description: Conductivity, Layer 3
 25 Mar 99

Visual MODFLOW v.2.7.2, (C) 1995-1997
 Waterloo Hydrogeologic, Inc.
 NC: 198 NR: 207 NL: 3
 Current Layer: 3

Figure B3 Model conductivity distribution - Layer 3

Attachment C

**PREDICTED GROUNDWATER LEVELS - 50 mm/yr
ACCESSION RATE WITHOUT PUMPING**

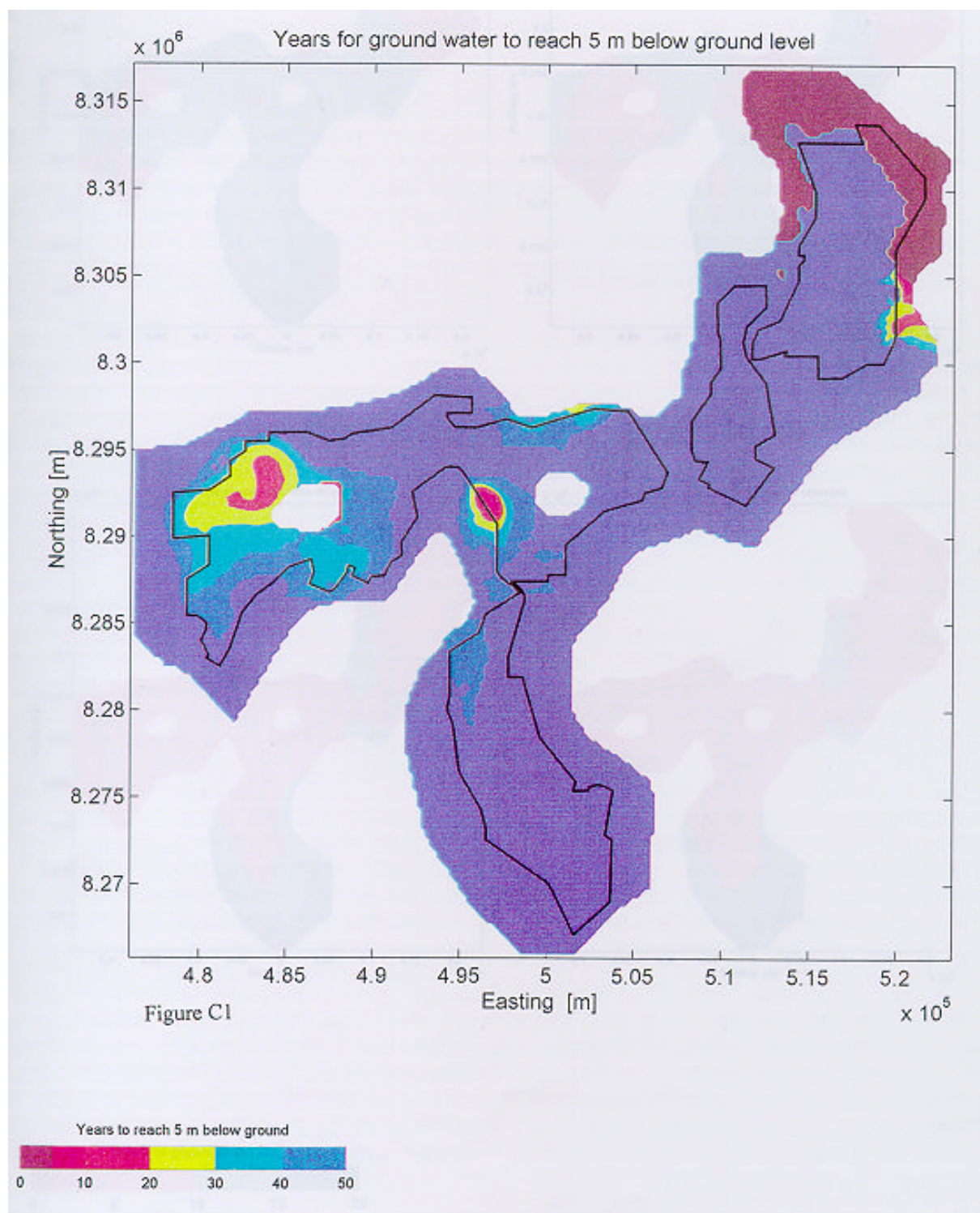


Figure C1 Groundwater levels – 50 mm/yr accession rate without pumping

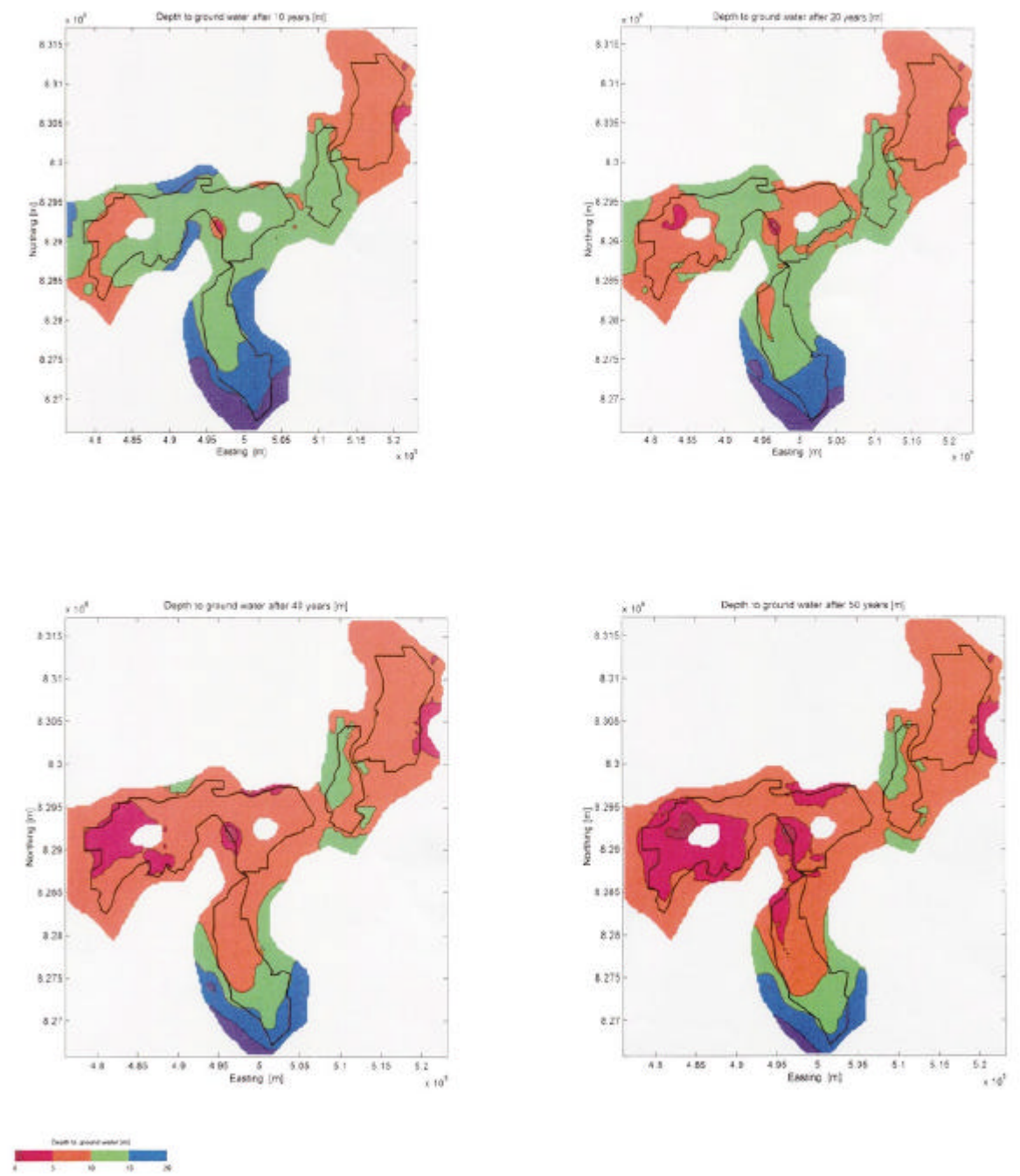


Figure C2 Groundwater levels – 50 mm/yr accession rate without pumping

Attachment D

**PREDICTED GROUNDWATER LEVELS - 50 mm/yr
ACCESSION RATE WITH PUMPING**

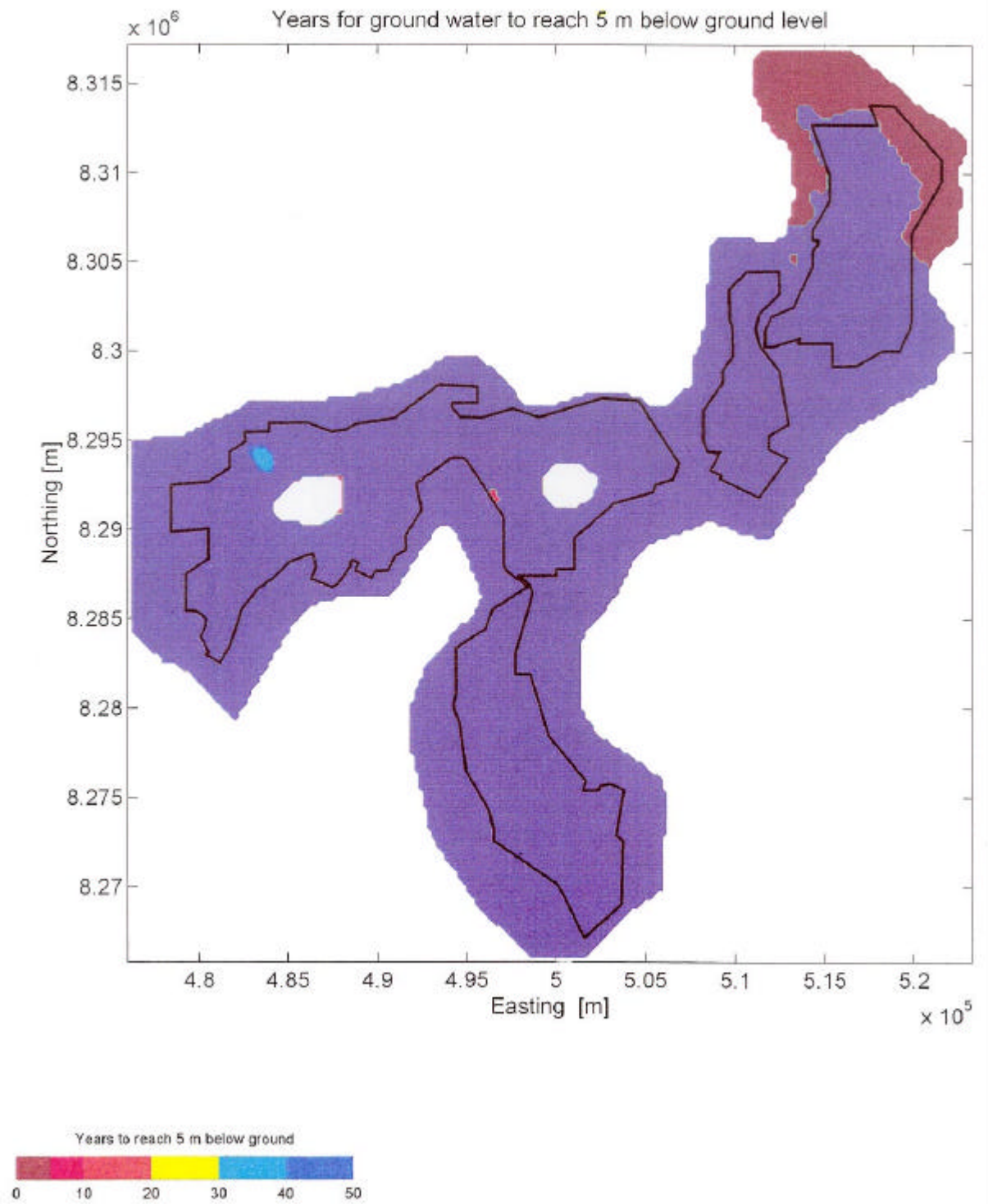


Figure D1 Groundwater levels – 50 mm/yr accession with pumping

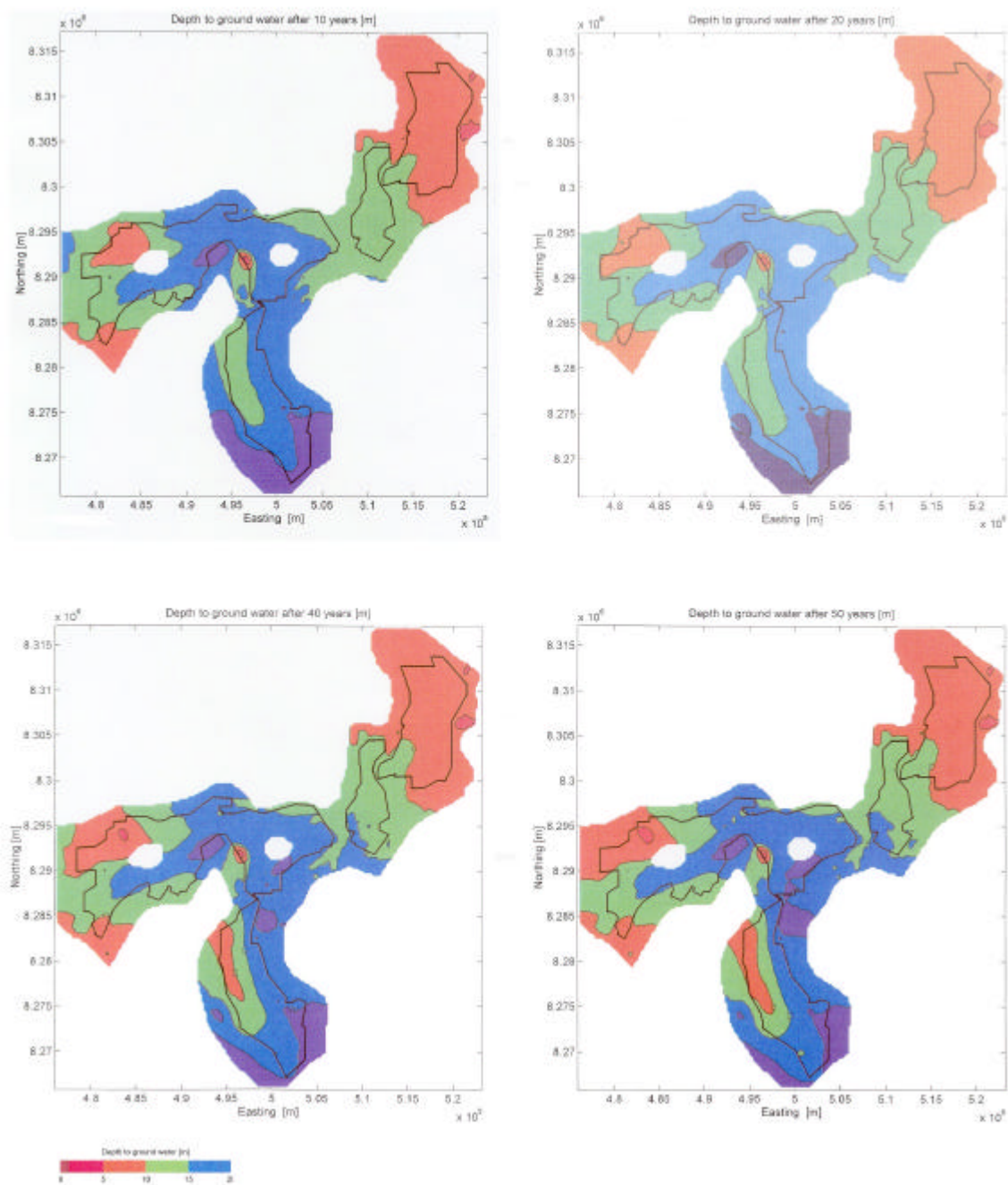


Figure D2 Groundwater levels – 50 mm/yr accession rate with pumping

**PREDICTED GROUNDWATER LEVELS - 100 mm/yr
ACCESSION RATE WITHOUT PUMPING**

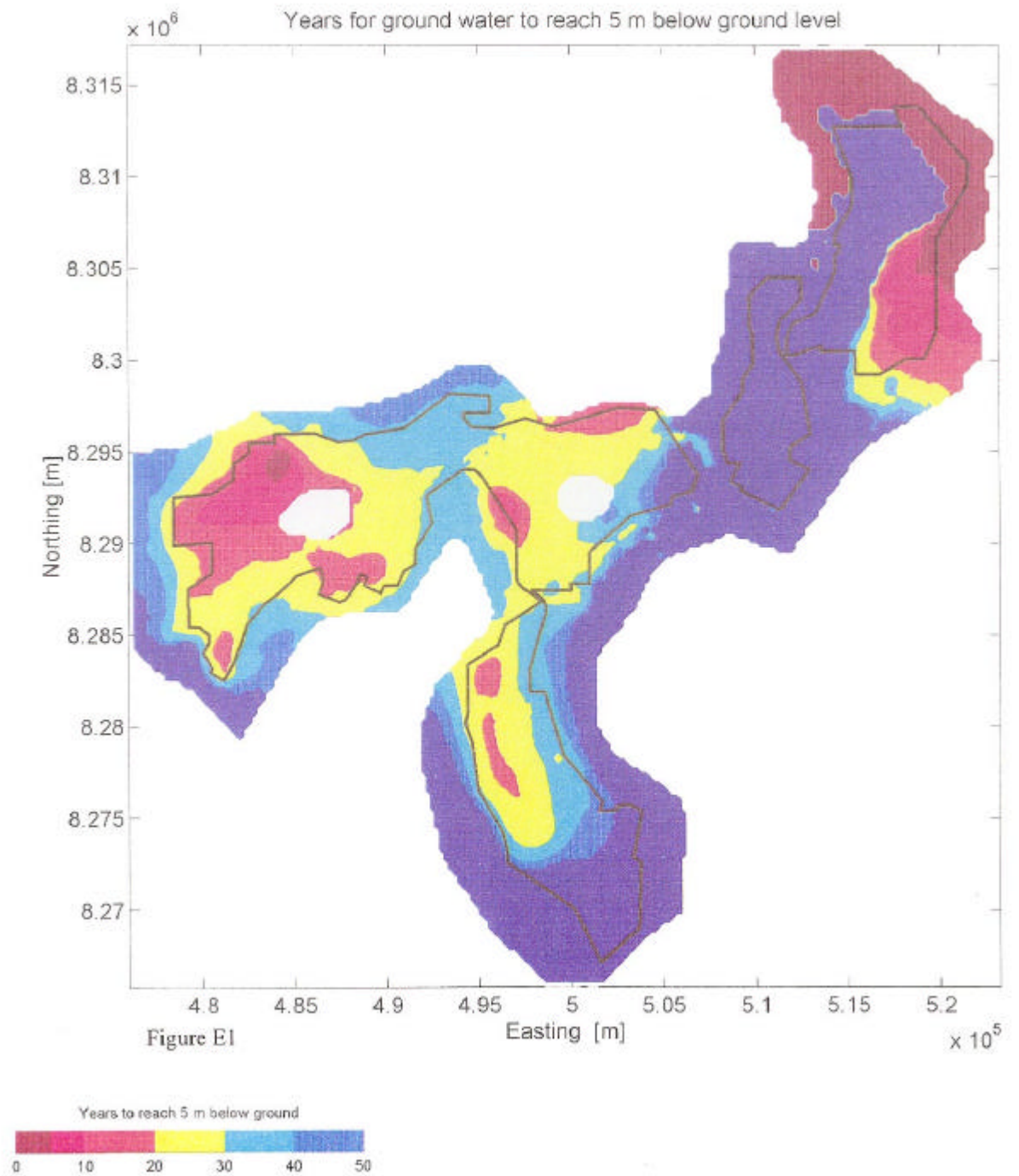


Figure E1 Groundwater levels – 100 mm/yr accession rate without pumping

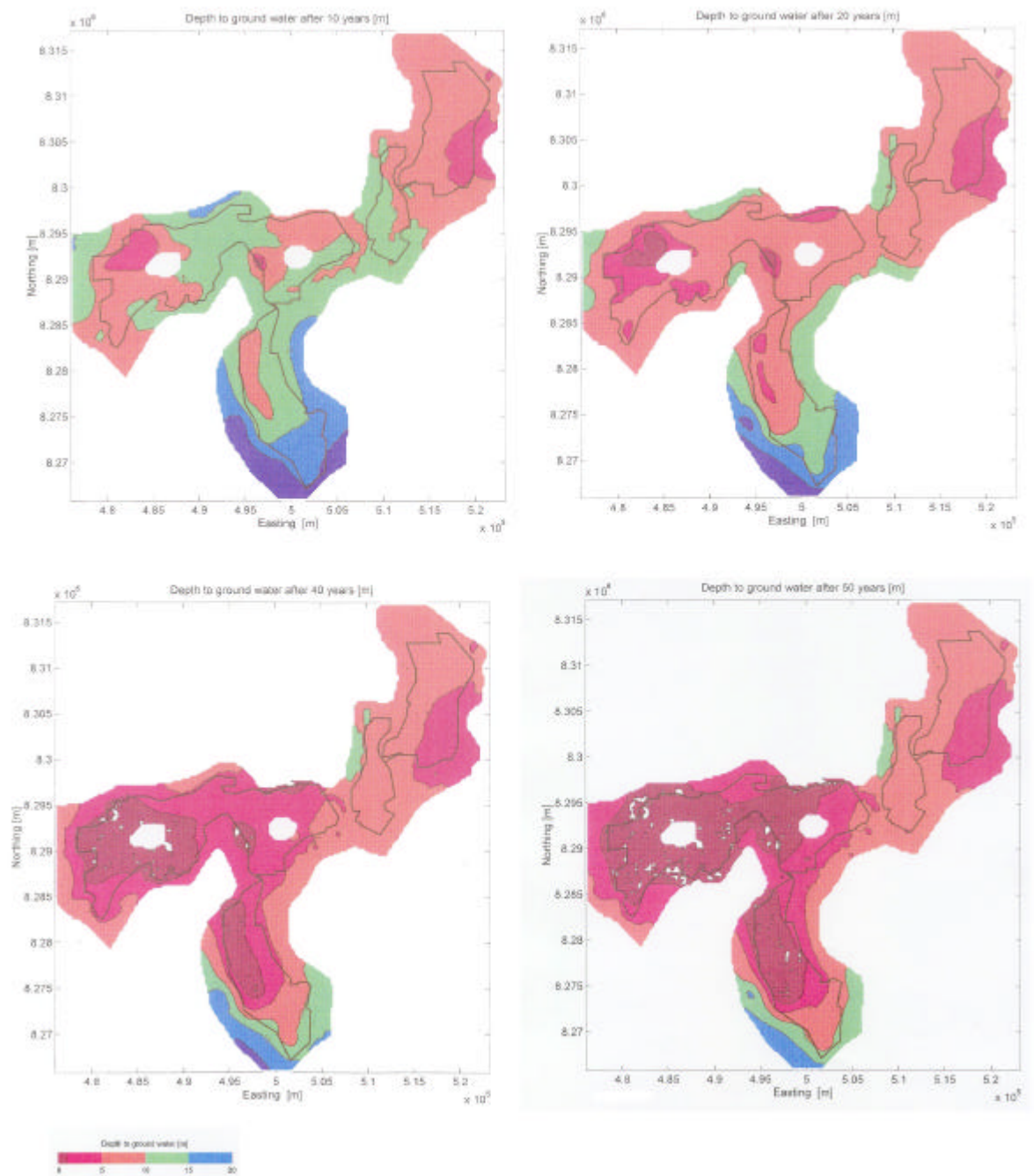


Figure E2 Groundwater levels – 100 mm/yr accession rate without pumping

Attachment F

**PREDICTED GROUNDWATER LEVELS - 100 mm/yr
ACCESSION RATE WITH PUMPING**

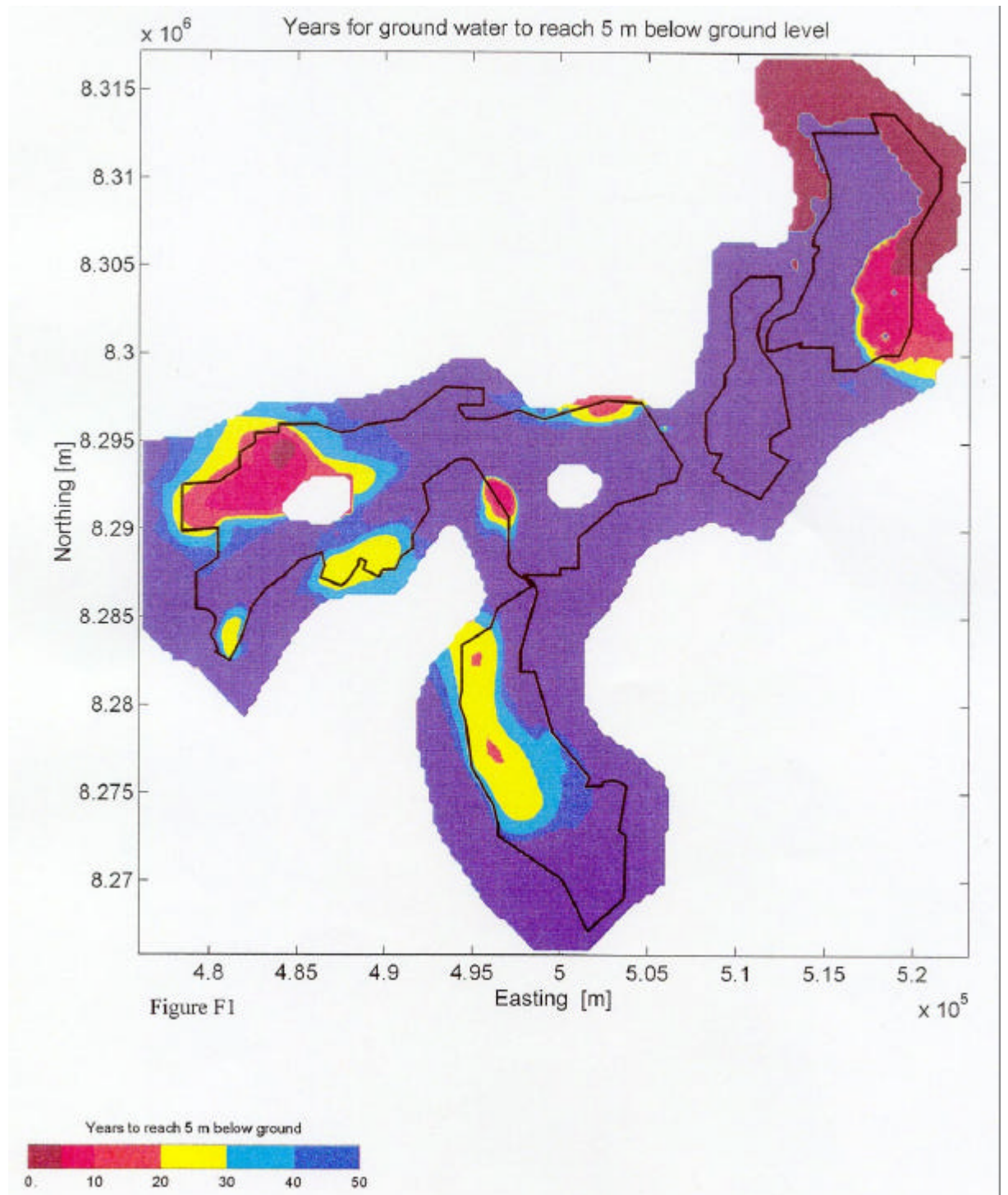


Figure F1 Groundwater levels – 100 mm/yr accession rate with pumping

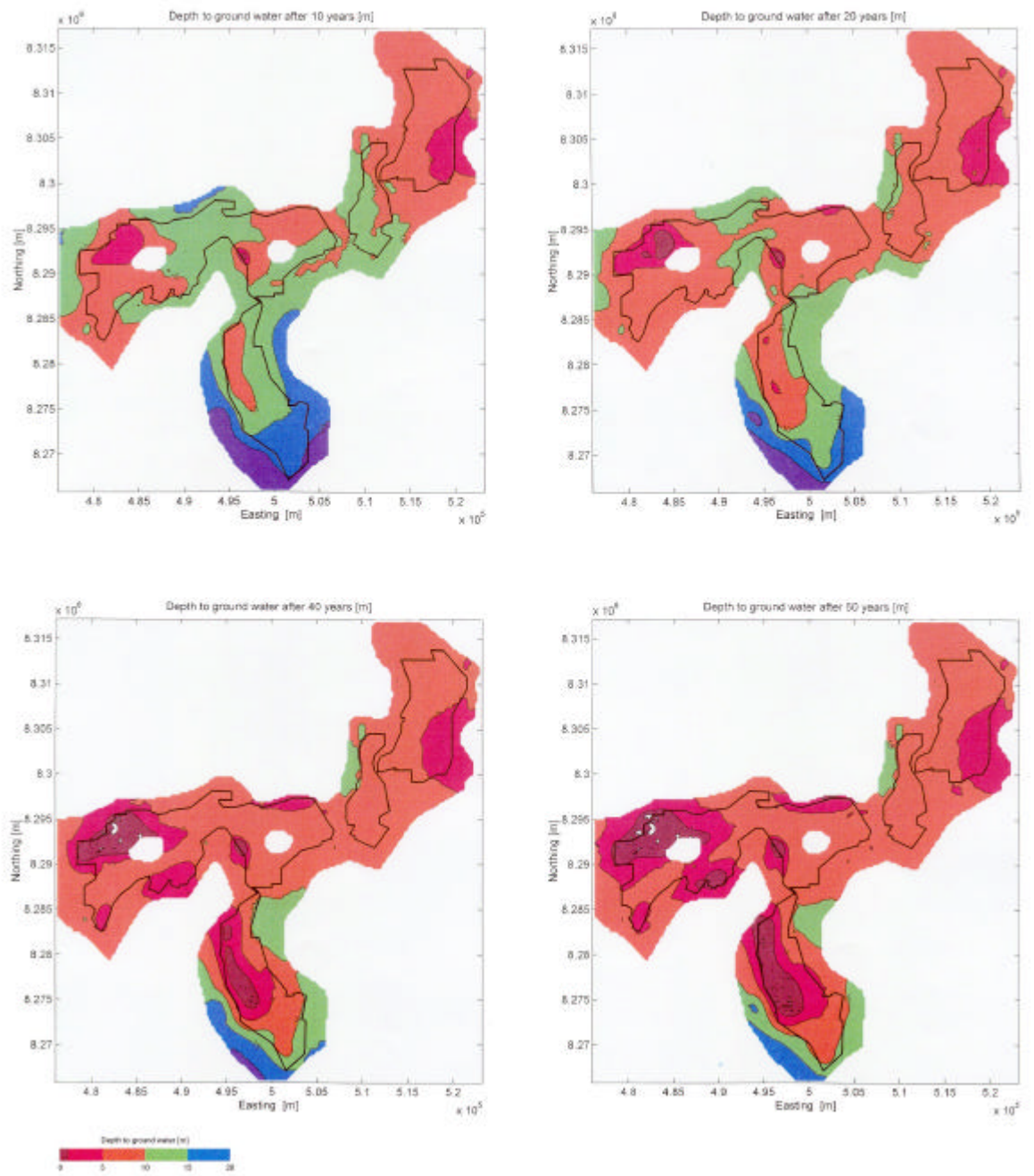


Figure F2 Groundwater levels – 100 mm/yr accession rate with pumping

Attachment G

**PREDICTED GROUNDWATER LEVELS - 150 mm/yr
ACCESSION RATE WITH PUMPING**

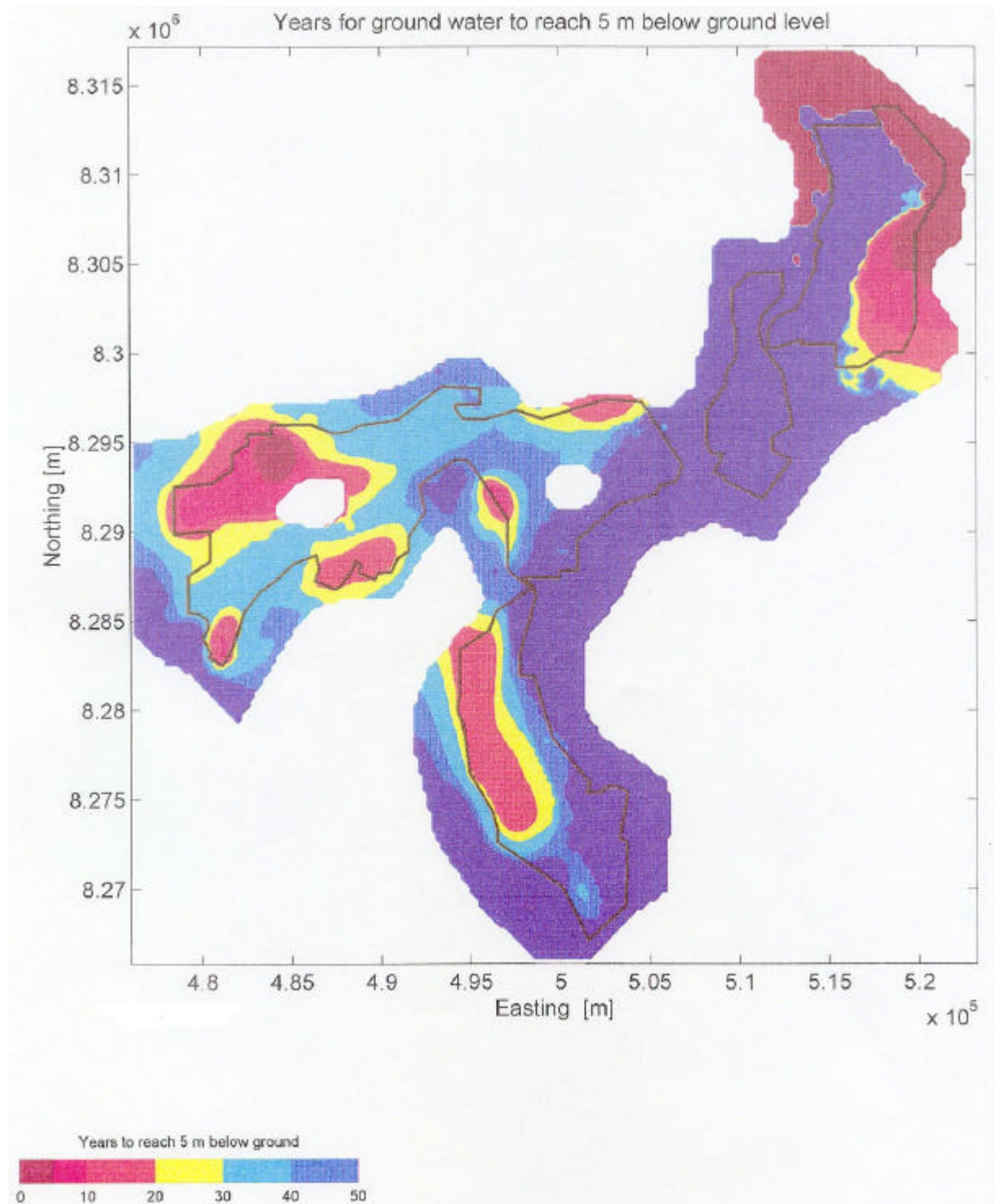


Figure G1 Groundwater levels – 150 mm/yr accession rate with pumping

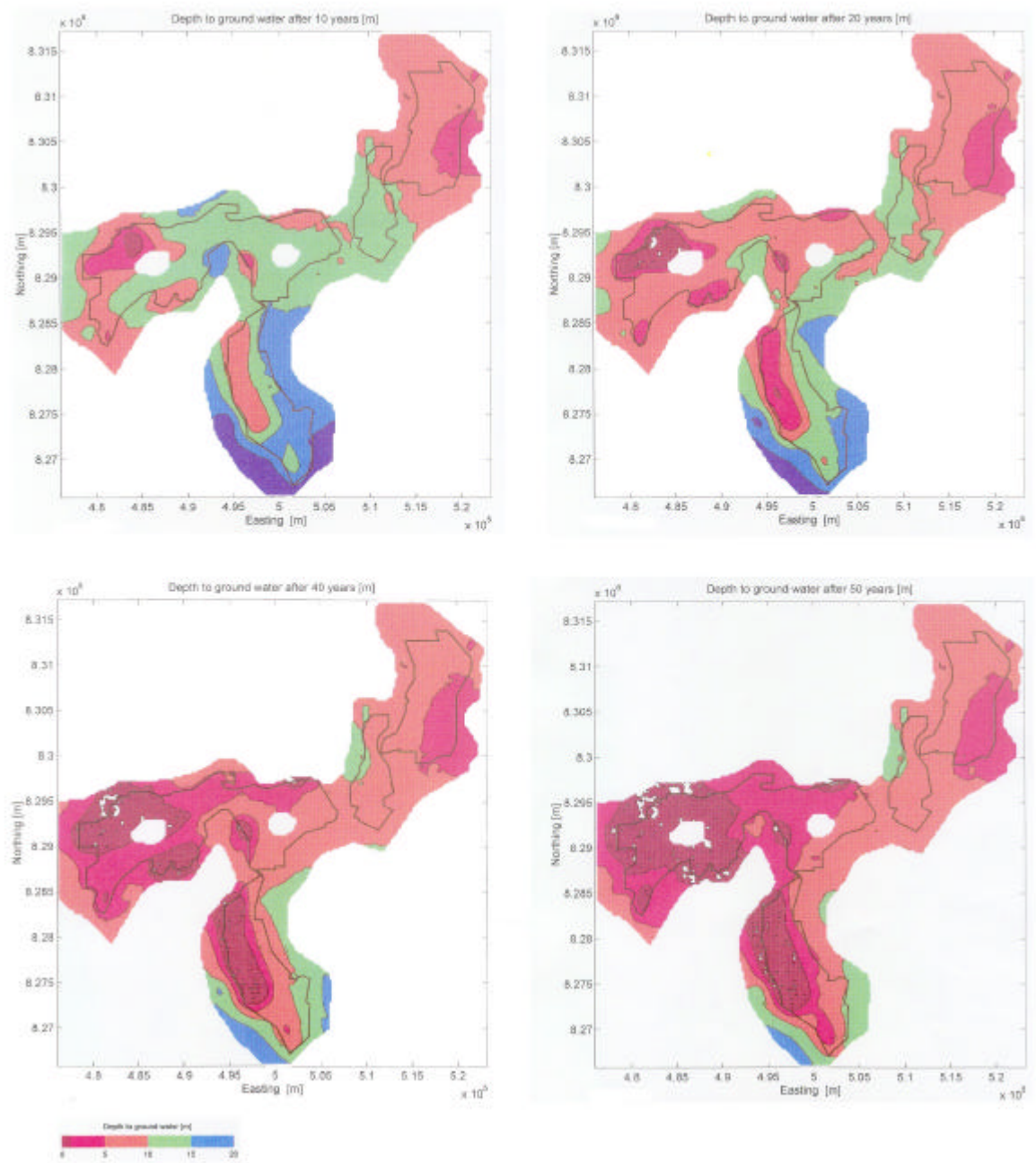


Figure G2 Groundwater levels – 150 mm/yr accession rate with pumping

APPENDIX J

BIOLOGICAL AND FAUNA SURVEYS OF THE PROPOSED DEVELOPMENT AREA

ORD SUGAR PROJECT

Biological Surveys of the Proposed Development Area - May and June 1999

Prepared for:

**WESFARMERS LIMITED,
MARUBENI CORPORATION AND THE WATER
CORPORATION OF WESTERN AUSTRALIA**
Level 7, 40 The Esplanade
Perth WA 6000

Prepared by:

Kinhill Pty Ltd
ACN 007 660 317
47 Burswood Road, Victoria Park WA 6100
Telephone 08 9362 5900, Facsimile 08 9362 5627

August 1999

© Wesfarmers Ltd, Marubeni Corporation and Water Corporation of Western Australia 1999

Limitations Statement

In preparing this report, Kinhill Pty Ltd has relied upon and presumed accurate certain information (or absence thereof) relative to the site that was obtained from examination of records in the public domain or provided by government officials and authorities. Except as otherwise stated in the report, Kinhill has not attempted to verify the accuracy or completeness of any such information.

The findings, observations and conclusions expressed by Kinhill Pty Ltd in this report are not, and should not be considered, an opinion concerning the feasibility of establishing irrigated agriculture on the site. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon information in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia, and is subject to and issued in connection with the provisions of the agreement with Kinhill Pty Ltd. Kinhill Pty Ltd accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

CONTENTS

Section	Page
1 BACKGROUND	
2 SCOPE AND STRUCTURE OF THIS REPORT	
3 REFERENCES	
ATTACHMENTS	
A	A Vegetation Survey to Map the Vegetation Communities of the M2 Development Area of the Ord River Irrigation Scheme
B	A fauna survey of the M2 Development Area of the Ord River Irrigation Scheme
C	A Survey of Bats for the Ord River Irrigation Stage 2 Project

1 Background

Kinhill Pty Ltd were contracted by Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia to co-ordinate a biological survey of the areas proposed for development as part of the Ord Sugar Project. These areas comprise portions of the black soil (cracking clay) plains of the Weaber Plain, Keep River Plain and Knox Creek Plain in the east-Kimberley region of Western Australia and the adjacent Northern Territory.

The purpose of the biological survey was to supplement data collected previously in the area by Ecologia Environmental Consultants in October 1996 and February 1997 (Ecologia Environmental Consultants 1997). Additional data was sought for:

- vegetation, to allow the preparation of a vegetation map for use in the Environmental Review and Management Programme / Environmental Impact Statement (ERMP/EIS) being prepared for the Ord Sugar Project (Chapter 7 of the ERMP/EIS refers);
- fauna inhabiting the black soil plains, particularly bats and other mammals, reptiles and frogs.

Two botanical field trips were undertaken from 17 – 20 May and 6 – 11 June 1999. The first field trip surveyed the Knox Creek and part of the Weaber Plain and the second completed the survey of the Weaber Plain and the Keep River Plain. The botanists who undertook the survey were Dr Eleanor Bennett and Mr Paul Ellery with assistance from Mrs Rochelle Pyle.

Five fauna specialists were part of the field survey undertaken between 6 – 11 June. This team comprised two bat specialists, Ms Lindy Lumsden and Ms Sue Churchill; two herpetologists Mr Peter Robertson and Mr Greg Harold, and one mammal specialist Dr Ray Hart. Mrs Rochelle Pyle again provided assistance to the team.

2 Scope and Structure of this Report

This report is a compilation of three reports prepared by the specialists who undertook the field surveys in May and June 1999.

Attachment A describes the vegetation communities of the Project Area. This report combines the field data of Ecologia Environmental Consultants (1997) and that from the Kinhill Pty Ltd fieldwork in 1999, from which the vegetation map of the area was prepared.

Attachment B describes the terrestrial fauna survey. The data included is from pitfall traps and opportunistic sightings undertaken by the team.

Attachment C describes the survey for bats undertaken in June 1999. In addition to the project area, recording for the presence of bats was also undertaken in the Point Spring Nature Reserve and adjacent to Cave Spring.

3 References

Ecologia Environmental Consultants (1997) Ord River Irrigation Area - Stage 2 M2 Development Area Terrestrial Biological Assessment. Unpublished report for Department of Resources Development, Perth.

Attachment A

**A Vegetation survey to map the vegetation communities of
the M2 Development Area of the Ord River Irrigation Scheme**

ORD SUGAR PROJECT

A Vegetation survey to map the vegetation communities of the M2 Development Area of the Ord River Irrigation Scheme

Prepared for:

**WESFARMERS LIMITED,
MARUBENI CORPORATION AND THE WATER
CORPORATION OF WESTERN AUSTRALIA**
Level 7, 40 The Esplanade
Perth WA 6000

Prepared by:

Kinhill Pty Ltd
ACN 007 660 317
47 Burswood Road, Victoria Park WA 6100
Telephone 08 9362 5900, Facsimile 08 9362 5627

October 1999

CONTENTS

Section	Page
1 INTRODUCTION	
2 METHOD	
3 RESULTS	
4 VEGETATION COMMUNITIES	
4.1 Grasslands and Sedgelands	4-5
4.2 Grasslands with Emergent Trees	4-7
4.3 Woodlands	4-10

1 Introduction

Two biological surveys had been undertaken in the M2 Development Area of the Ord River Irrigation Scheme by Ecologia Environmental Consultants (Ecologia) in October 1996 and February 1997. These surveys were commissioned by the Department of Resources Development on behalf of the Governments of Western Australia and the Northern Territory.

The Ecologia surveys were undertaken over the whole of the proposed development area plus some additional areas outside. A total of 17 vegetation associations were recognised from the data obtained. An attempt was made by Kinhill Pty Ltd to produce a vegetation map of the area from the field data obtained by Ecologia, but as found by Ecologia, this was impossible. Many vegetation associations were not soil specific and the 17 vegetation associations encompassed too much variation. In addition, when the sampling sites were overlain on aerial photography, it was apparent that the proposed development area had been inadequately surveyed by comparison to the surrounding country.

The purpose of the additional field work undertaken by Kinhill Pty Ltd was to ground truth a draft vegetation map and to enhance an understanding of the vegetation of the proposed development area, particularly the cracking clay soils. Rock outcrops and riparian areas were not surveyed as these would not be subject to development.

2 Method

Two field trips were undertaken, the first from 17 – 20 May and the second from 6 – 11 June, 1999. Knox Creek Plain and the western section of the Weaber Plain were surveyed in the first field trip and the remainder of the Weaber Plain and the Keep River Plain in the second trip.

The information gathered by Ecologia, including vegetation description, species present and soil type were checked in the field and alterations and enhancements made where appropriate. As these field trips were undertaken at the end of the wet season there were several annual species still flowering which had not been collected during the Ecologia surveys.

Aerial photographs with the soil units superimposed were used in the field. Differences observed in the aerial photographs were surveyed, however access was limited to tracks. Also the *Sorghum* spp. plants were over 3m tall and the grass understorey extremely dense, making cross country access very difficult. The tracks were abundant and transected the different soil units and vegetation variations seen in the aerial photograph.

All the proposed development area was successfully covered by the Ecologia and Kinhill survey, encompassing the extent and diversity of the vegetation associations.

Additional sites were recorded where the vegetation was found to differ from that recorded by Ecologia. At each new site the following was recorded: soil unit, AMG, each species present, its average height, % cover alive and dead, overall community and a vegetation description. Each site was then entered on the aerial photograph to check the extent of that community.

Collections were made of all readily observed species in the field and representative collections will be sent to the Western Australian Herbarium, Darwin Herbarium and the CALM Herbarium at Kununurra. All specimens were pressed and dried and then checked with named specimens housed at the Western Australian Herbarium. Mr Bruce Maslin from the Western Australian Herbarium is thanked for the identification of the wattle species, especially the dominant species, *Acacia ditricha*.

3 Results

The vegetation of the proposed development area was found to consist of grassland or grassland with emergent trees, occasionally the trees forming a moderately dense canopy. Most grasses and trees were common across all the plains but some species were found to be soil specific (e.g. *Melaleuca minutifolia*) or to occur in damper soil (e.g. *Oryza australiensis*).

The riparian vegetation along the Keep River varied considerably. No specific survey sites were established in these areas but the Keep River was crossed on several tracks and Ecologia sites were visited for confirmation of species and vegetation description. In the northern section the vegetation was open and dominated by *Melaleuca acacioides* and *Bauhinia cunninghamii* with an open to dense understorey of *Heteropogon contortus* and *Panicum decompositum*. Scattered seedlings of the mangrove, *Avicennia marina* were observed but there was no fringing vegetation of this or any other species of mangrove. The vegetation became dense upstream, resembling vine thicket density in several areas, but without the presence of dense vines. In the denser areas the vegetation consisted of trees of *Melaleuca argentea*, *Barringtonia acutangula*, *Melaleuca viridiflora* and *Celtis phillipensis* with scattered *Pandanus aquatica* over open grassland dominated by *Panicum laevinode*. The scattered vines included *Marsdenia* sp. *Cardiosperma halicabum* and *Ipomoea muelleri*.

Basically the species present on the Weaber Plain, Keep River Plain and Knox Creek Plain were very similar, varying mainly in the density of each layer and species combination. There were some dominant changes, which are listed below.

- The northern section of the Keep River Plain was dominated by grasslands with no emergent trees whereas the Knox Creek Plain had grasslands with emergent *Eucalyptus microtheca*, *Bauhinia cunninghamii* and *Excoecaria parvifolia*. The Weaber Plain was very similar to the Knox Creek Plain but included *Terminalia obovata* subsp. *volucris* as a dominant low tree.
- *Iseilema vaginiflora* was one of the dominant grasses on the Knox Creek and Weaber Plains and *Iseilema fragile* was a dominant grass on the Keep River Plain.
- *Acacia diticha* was more abundant in the Keep River Plain than on the other two plains, and *Terminalia obovata* subsp. *volucris* was more abundant on the Weaber Plain than the other two plains.
- The Keep River Plain included several areas of different soil types with distinctive vegetation present. The variation in soils was not as distinct in the Knox Creek and Weaber Plains with only nominal soil variation being present.
- The northern section of the Weaber Plain tended to be retaining its moisture for a longer period than the remainder of the area as evidenced by the presence of *Oryza australiensis* and *Echinochloa kimberleyensis*.

Currently the area is used for pastoral purposes and the vegetation shows the effects of this land use. Cattle congregate at areas retaining water, and permanent water holes with cattle access are highly degraded.

In addition, fire appears to have been through several of the bushland areas at different frequencies. Between the survey in May and June 1999, areas of the Weaber Plain had been burnt and the grasses had been severely damaged and several shrubs killed making identification impossible. The long term effect of frequent fires is not fully understood but could have the capacity to change a woodland or shrubland to an open woodland or shrubland or even grassland. The dominance of individual grass species as a result of the fire cycle is also not fully understood and certain species may benefit from frequent fires while others may not survive.

4 Vegetation Communities

The following descriptions are derived from Ecologia (1997) Appendix C and the field work by Kinhill Pty Ltd.

A total of 72 vegetation communities are described and these are grouped into 17 different categories dependent upon the dominant vegetation storey. One community, G7 is described but is too small to map even at a 1:25000 scale and is therefore combined and mapped with vegetation community GT3. Connors et.al. (1996) used fine scale mapping units for their work in the Northern Territory, however the communities described below are at an even finer scale mapping unit.

4.1 GRASSLANDS AND SEDGELANDS

G1 Dense Grassland mosaic dominated by *Heteropogon contortus*, *Iseilema fragile*, *Themeda triandra*, *Chrysopogon fallax* or *Sorghum timorense*.

Grasses included *Heteropogon contortus* or *Iseilema fragile* or *Themeda triandra* and *Sorghum timorense* with cover between 50-90%. Additional grasses included *Ophiuros exaltatus*, *Aristida latifolia*, *Dichanthium sericeum*, *Sehima nervosum* and *Panicum decompositum*.

Shrubs with a total cover <1% included *Hibiscus panduriformis*, *Acacia ditricha* and *Sida spinosa*.

This community occurred in Soil Unit 1 on the Keep River Plain where it formed pure grasslands.

G2 Dense Grassland of *Themeda triandra*, *Dichanthium sericeum* var. *polystachyum*, *Sorghum timorense* and *Chrysopogon fallax*.

Grasses included *Themeda triandra* and *Dichanthium sericeum* var. *polystachyum* with cover ca. 35%, *Themeda triandra*, *Sorghum ? grande* with cover 65%, *Chrysopogon fallax* and *Ophiuros exaltatus* with cover <5% and *Dichanthium sericeum* var. *polystachyum* with cover <10%.

Occasional shrubs included *Terminalia oblongata* subsp. *volucris*, *Neptunia monosperma* and *Hibiscus panduriformis*.

This community occurred in Soil Unit 3a on the Keep River Plain.

G3 Open Grassland of *Themeda triandra* over *Eriachne* sp.

Grasses included *Eriachne* sp. with cover >50%, *Themeda triandra* with cover 1-2% and *Chrysopogon setifolius* with cover <1%.

Scattered juvenile *Eucalyptus microtheca* up to 1.3m tall were recorded.

This community occurred in Soil Unit 1 on the Keep River Plain.

G4 Open annual grassland of *Sorghum timorense* over dense *Chrysopogon fallax*

Grasses included *Sorghum timorense* with cover 20-50%, *Chrysopogon fallax* with cover 60-90%. Other grass species included *Themeda triandra*, *Iseilema fragile*, *Aeschynomene indica*, *Dichanthium sericeum* var. *polystachyum*, *Fimbristylis phaeoleuca*, *Panicum laevinode* and *Eriachne glauca*.

This community occurred in Soil Unit 5c towards the east of the Keep River Plain.

G5 Open Grassland of *Imperata cylindrica* over *Xerochloa imberbis* and *Sporobolus virginicus*.

Grasses included *Imperata cylindrica* with cover >85%, *Xerochloa imberbis* with cover >40% and *Sporobolus virginicus* with cover >5%.

Shrubs included **Melochia pyramidata* and *Melaleuca nervosa*.

Occurred in Soil Unit 7a on the Keep River Plain beside Border Creek.

G6 Mixed Sedgeland and Grassland of *Eriachne sulcata*, *Eleocharis dulcis* and *Eleocharis* sp. B (Kimberley Flora) with emergent *Corymbia confertiflora*.

Grasses included *Eriachne sulcata*, *Eleocharis* sp. B (Kimberley Flora) with cover >30%, *Eleocharis dulcis* with cover >10%, *Sorghum timorense* with cover <20%, *Oryza australiensis* with cover <5%. *Themeda triandra* occurred in clumps with an overall cover <5%.

Emergent trees included *Corymbia confertiflora*.

This community was recorded at a swamp in Soil Unit 5c/4d on the Weaber Plain.

G7 Open Sedgeland dominated by *Eleocharis dulcis* and *Schoenoplectus praelongatus* with emergent *Excoecaria parvifolia* and *Barringtonia acutangula* on the edge of Milligan's Lagoon.

This community for mapping purposes has been combined with community GT3. However in the lagoons to the south of the windpump where the banks are not steep there is an open sedgeland.

Living in the water were *Pseudoraphis spinescens* and *Eleocharis dulcis* with cover >30%, *Nymphaea violacea* and *Nymphaea gigantea* with cover >10%, *Utricularia muelleri* floating on the surface with cover about 2%. Surrounding the water, but in damp ground, was *Schoenoplectus praelongatus* with cover >8% and *Schoenoplectus dissachanthus* with cover

<1%, *Marsilea angustifolia* with cover <2%. Shrubs included *Excoecaria parvifolia* with cover >5% and *Barringtonia acutangula* with cover 3%.

Occurs in Soil Unit 1, on the Knox Plain at Milligan's Lagoon.

4.2 GRASSLANDS WITH EMERGENT TREES

GT1 Tall Grassland of *Sorghum timorense*, *Aristida latifolia* and *Heteropogon contortus* with emergent *Eucalyptus microtheca* in Soil Unit 1 on the Keep River Plain.

Trees included *Eucalyptus microtheca* with cover 4% and *Excoecaria parvifolia* cover <1%.

Grasses included *Sorghum timorense* with cover >80%, *Themeda triandra* with cover <5%, *Iseilema fragile* <2% and *Aristida latifolia* with cover 1%.

This Community had a restricted distribution in Soil Unit 1 on the Keep River Plain

GT2 Dense grassland of *Iseilema vaginiflorum*, *Aristida latifolia*, *Sorghum timorense*, *Themeda triandra* with emergent *Eucalyptus microtheca*, *Excoecaria parvifolia*, *Atalaya hemiglauca* and *Bauhinia cunninghamii*.

Trees included *Eucalyptus microtheca* with cover <5%, *Excoecaria parvifolia* with cover <15%, *Bauhinia cunninghamii* with cover <10% and *Atalaya hemiglauca* with cover <5%.

Shrubs included *Corchorus fascicularis* with cover 0-25% and *Flemingia pauciflora* with cover <5%.

Grasses included *Iseilema vaginiflorum* with cover 20-45%, *Sorghum timorense* with cover <40%, *Aristida latifolia* with cover <40%, *Brachyachne convergens* of <30%, *Themeda triandra* with cover <15% and *Ophiuros exaltatus* with cover <5%.

This was the dominant community in Soil Unit 1 on the Knox Creek Plain. It consisted of a mosaic of different grass species with the same upper storey species.

GT3 Grassland of *Panicum decompositum*, *Heteropogon contortus*, *Themeda triandra* and *Iseilema vaginiflorum* with emergent scattered *Eucalyptus microtheca* and *Corymbia bella*.

Trees included *Eucalyptus microtheca* with cover 1-2%, *Corymbia bella* with cover <10%, *Cathormion umbellatum* subsp. *moniliforme* with cover <15%, **Leucaena leucocephala* with cover <3% and *Bauhinia cunninghamii* with cover <3%.

Shrubs included *Abutilon hannii* with cover <1%, *Phyllanthus maderaspatensis* with cover <5%, *Grewia retusifolia* with cover <1%.

Twiningers included *Passiflora foetida* var. *hispida* and *Ipomoea muelleri*.

Grasses included *Panicum decompositum* with cover <20%, *Iseilema vaginiflorum* with cover <20%, *Mnesithea rottboellioides* with cover <5% and *Eragrostis tenellula* with cover <2%.

This community occurred on the raised bank on the eastern edge of Milligan's Lagoon in Soil Unit1.

GT4 Grassland dominated by *Themeda triandra* and *Aristida latifolia* with emergent trees of *Eucalyptus microtheca*.

Trees included *Eucalyptus microtheca* with cover <2%.

Shrubs included *Neptunia monosperma* with cover <2% and *Phyllanthus maderaspatensis* with cover <1%

Grasses included *Themeda triandra* with cover 50-70%, *Sorghum timorense* with cover 10-15%, *Aristida latifolia* with cover <10% and *Iseilema vaginiflorum* with cover <5%.

This community occurred in Soil Unit 5a on the southern area of the Keep River Plain.

GT5 Grassland dominated by *Iseilema vaginiflorum* with emergent *Eucalyptus microtheca* and emergent to dense *Excoecaria parvifolia*.

Trees included *Eucalyptus microtheca* with cover <2%, *Excoecaria parvifolia* with cover 2-30% and *Acacia ditricha* with cover <1%.

Grasses included *Iseilema vaginiflorum* with cover 60-70%, *Chionachne hubbardiana* with cover <5%, *Panicum decompositum* with cover <5% and *Sorghum timorense* with cover <5%.

This community occurred in Soil Unit 5b on the Weaber Plain.

GT6 Grassland of *Cymbopogon procerus* and *Themeda triandra* with emergent *Bauhinia cunninghamii* and *Acacia ditricha*.

Trees included *Bauhinia cunninghamii* with cover <1% and *Acacia ditricha* with cover <1%.

grasses included *Themeda triandra* with cover 50-60%, *Cymbopogon procera* with cover 15-30% and *Ophiuros exaltatus* with cover <5%.

This community occurred in Soil Unit 4a on the Keep River Plain.

GT7 Grassland of *Bothriochloa bladhii*, *Themeda triandra* and *Ophiuros exaltatus* with emergent *Eucalyptus microtheca*, *Acacia ditricha* and *Bauhinia cunninghamii*.

Trees included *Eucalyptus microtheca* with cover <2%, *Bauhinia cunninghamii* with cover <1%, *Acacia ditricha* with cover <1% and *Excoecaria parvifolia* with cover <1%.

Grasses included *Bothriochloa bladhii* with a cover 45-55%, *Themeda triandra* with cover 10-15%, *Ophiuros exaltatus* with cover 10-15%.

This community occurred in Soil Unit 7a along a small creek and flood plain on the Keep River Plain.

GT8 Grassland of *Themeda triandra*, *Iseilema vaginiflorum* and *Aristida latifolia* with scattered *Bauhinia cunninghamii*, *Acacia ditricha* and *Corymbia bella* and shrubs of *Flemingia pauciflora*.

Trees included *Bauhinia cunninghamii* with cover <10%, *Corymbia bella* with cover 3-10% and *Acacia ditricha* with cover <10%.

Shrubs dominated by *Flemingia pauciflora* with cover 25-40%.

Grasses included *Themeda triandra* with cover 2-20%, *Iseilema vaginiflorum* with cover 5-60%, *Aristida latifolia* with cover 1-50% and *Chionachne hubbardiana* with cover <5%.

Occurred in Soil Unit 1 on the Weaber Plain.

GT9 Open tussock and annual grassland of *Eulalia aurea*, *Panicum decompositum* and *Sorghum timorense* with emergent *Corymbia bella* and **Parkinsonia aculeata*.

Trees included scattered *Corymbia bella* and **Parkinsonia aculeata*.

Shrubs included *Barringtonia acutangula* and *Hibiscus panduriformis*.

Grasses included *Eulalia aurea*, *Panicum decompositum*, *Sorghum timorense*, *Aristida latifolia*, *Ophiuros exaltatus* and *Cyperus conicus*.

This community occurred at a swamp in Soil Unit 5a on the Weaber Plain just off the proposed area for development, on the southern edge of the Weaber Range.

GT10 Open Hummock grassland dominated by *Triodia bynoei* with Open Shrubland of *Calytrix exstipulata* and scattered low trees of *Buchanania obovata*, *Owenia vernicosa* and *Corymbia confertiflora*.

Trees included *Buchanania obovata*, *Owenia vernicosa* and *Corymbia confertiflora*.

Shrubs included *Melaleuca alsophila*, *Calytrix exstipulata*, *Ficus platypoda*, *Solanum horridum* and *Phyllanthus reticulatus*.

Grasses included *Heteropogon contortus*, *Bulbostylis barbata*, *Triodia bynoei* and *Cyperus cunninghamii*.

This community occurred in Soil Unit 6 on the Weaber Plain on a sandstone ridge which had a narrow sandy margin.

GT11 Open annual grassland and herbfield of *Neptunia monosperma* with emergent trees of *Atalaya salicifolia* and *Excoecaria parvifolia*.

Trees included *Atalaya salicifolia* with cover <2%, *Excoecaria parvifolia* with cover <2% and *Eucalyptus microtheca* with cover <1%.

Shrubs included *Terminalia oblongata* subsp. *volucris*, *Cathormion umbellatum* subsp. *moniliforme* and *Acacia ditricha*.

Herbs included *Neptunia monosperma* with cover 2-10%.

Grasses included *Sorghum timorense* with cover 10-30%, *Chrysopogon fallax* and *Dichanthium fecundum* with cover 10-30%, *Aristida latifolia*, *Panicum decompositum* and *Astrebla elymoides*.

This community occurred in Soil Unit 9c on the Weaber Plain.

GT12 Open Grassland of *Sehima nervosum* and *Themeda triandra* with scattered trees of *Bauhinia cunninghamii*, *Adansonia gregorii*, *Corymbia foelscheana* and *Eucalyptus microtheca*.

Trees included *Eucalyptus microtheca*, *Corymbia confertiflora*, *Corymbia foelscheana*, *Melaleuca minutifolia*, *Acacia ditricha* and *Adansonia gregorii* with a total cover <5%.

Grasses included *Themeda triandra* with cover 60-90%, *Sehima nervosum* with cover <5-20%, *Sorghum plumosum* with cover <5% and *Ophiuros exaltatus* with cover <5%.

Occurred in Soil Unit 2b on the Keep River Plain.

GT13 Moderately dense tussock and annual grassland of *Chrysopogon fallax*, *Themeda triandra* and *Iseilema fragile* with emergent low trees of *Corymbia bella*, *Excoecaria parvifolia* and *Bauhinia cunninghamii*.

Trees included *Bauhinia cunninghamii* with cover <2%, *Corymbia bella* with cover <1%, *Atalaya salicifolia* with cover <1%, and *Excoecaria parvifolia* with cover <1%.

Shrubs included *Grewia retusifolia* and *Carissa lanceolata*.

Grasses included *Chrysopogon fallax* and *Themeda triandra* with cover 30-70%, *Iseilema fragile* with cover 10-30%, *Panicum decompositum*, *Aristida latifolia*, *Dichanthium sericeum* subsp. *polystachyum*

This community occurred in Soil Unit 5c on the Weaber Plain.

GT14 Open grassland and herbland of mixed species with emergent *Eucalyptus microtheca*, *Corymbia bella* and *Adansonia gregorii*.

Trees included *Eucalyptus microtheca* with cover <2%, *Adansonia gregorii* with cover <1% and *Corymbia bella* with cover <1%.

Herbs included <1% cover *Waltheria indica*, *Bonamia linearis*, *Mitrasacme gentianeae*, *Drosera lanata*, *Stackhousia intermedia*, *Indigofera colutea*, *Indigofera linifolia* and *Mitrasacme exserta*.

Grasses included *Themeda triandra* with cover 10-15%, *Eriachne obtusa* with cover <5%, *Sorghum plumosum* and *Enneapogon purpurascens*.

This community occurred in Soil Unit 11 at the base of a rock outcrop on the Knox Creek Plain.

4.3 WOODLANDS

Woodlands of *Eucalyptus microtheca*, *Atalaya hemiglaucula*, *Bauhinia cunninghamii* and *Excoecaria parvifolia*

Em1 Dense Woodland of *Eucalyptus microtheca* over a grassland of *Iseilema vaginiflorum* and *Aristida latifolia*.

Trees only *Eucalyptus microtheca* with cover 10-30%.

Shrubs and Herbs included *Hibiscus panduriformis*, *Flemingia pauciflora*, *Indigofera colutea*, and *Spermacoce exserta*.

Grasses included *Iseilema vaginiflorum* with cover 10-40%, *Aristida latifolia* with cover 10-40% and *Panicum decompositum* with cover <10%.

Occurred in Soil Unit 1 on the western edge of the Knox Creek Plain near the Pincombe Plain.

Em2 Woodland of *Eucalyptus microtheca* over open *Bauhinia cunninghamii* and *Atalaya hemiglauc*a over a grassland of *Chrysopogon fallax*, *Iseilema vaginiflorum* and *Brachyachne convergens*.

Trees included *Eucalyptus microtheca* with cover <5%, *Bauhinia cunninghamii* with <5% cover and *Atalaya hemiglauc*a with <1% cover.

Shrubs and Herbs included *Sesbania cannabina* with cover <5%, *Neptunia monosperma*, *Corchorus fascicularis*, *Sida spinosa*, *Phyllanthus maderaspatensis* and *Stemodia tephropelina*.

Grasses included *Chrysopogon fallax* with 40% cover, *Brachyachne convergens* with 10-15% cover, *Iseilema vaginiflorum* with up to 50% cover.

This community occurred in Soil Unit 1g on the Knox Creek Plain close to the Keep River.

Em3 Woodland of *Eucalyptus microtheca* over a grassland of *Themeda triandra* and *Chrysopogon fallax*.

Trees included *Eucalyptus microtheca* and scattered occurrences of *Bauhinia cunninghamii* and *Atalaya hemiglauc*a.

Grasses included *Chrysopogon fallax* with cover 50-80%, *Themeda triandra* with cover 50-80%, *Ophiuros exaltatus* with cover 30% and *Sehima nervosum* with cover <5%.

This community occurred in Soil Unit 4b on the Knox River Plain.

Em4 Woodland of *Eucalyptus microtheca* and *Excoecaria parvifolia* over sedge-grassland of *Aristida latifolia*, *Panicum decompositum*, *Chrysopogon fallax*, *Panicum laevinode*, *Sorghum timorense* or *Iseilema fragile*.

Trees included *Excoecaria parvifolia* with cover 10-30%,

Herbs included *Corchorus fascicularis* with cover 2-10%, *Sida spinosa* with cover 2-10%

Grasses included *Sorghum stipoides* and *Sorghum timorense* with cover 30-70%, *Aristida latifolia* with cover 10-30%, *Chrysopogon fallax* with cover 10-30%, *Panicum decompositum* and *Eulalia aurea* with cover 10-70%, *Panicum laevinode* with cover 10-30% and *Iseilema fragile* with cover >40%.

This community occurred in Soil Unit 5a on the Knox and Weaber Plains.

Em5 Woodland of *Eucalyptus microtheca* and *Bauhinia cunninghamii* over a closed tussock grassland of *Themeda triandra* and *Ophiuros exaltatus*.

Trees included *Eucalyptus microtheca* and *Bauhinia cunninghamii* with cover 10-30%.

Shrubs and Herbs included *Hibiscus panduriformis*, *Rhynchosia minima* and *Neptunia monosperma*.

Grasses included *Themeda triandra* and *Ophiuros exaltatus* with cover 70-100%, *Iseilema vaginiflorum* with cover 2-10%, *Chrysopogon fallax*, *Aristida latifolia* and *Panicum decompositum*.

This community occurred in Soil Unit 7b on the Weaber Plain.

Em6 Open Woodland of *Eucalyptus microtheca*, *Bauhinia cunninghamii*, *Excoecaria parvifolia* and *Atalaya hemiglauca* over an open shrubland of *Terminalia oblongata* subsp. *volucris* open grassland of *Astrebla squarrosa*, *Aristida latifolia* and *Panicum decompositum*.

Trees included *Atalaya hemiglauca* with cover 10-15%, *Bauhinia cunninghamii* with cover <5-15%, *Acacia ditricha* with cover 1-2% and *Excoecaria parvifolia* with cover <1-15%.

Shrubs and Herbs included *Abelmoschus ficulneus*, *Corchorus fascicularis* and *Trichodesma zeylanicum* var. *latisepalum*.

Grasses included *Astrebla squarrosa* with cover 10-60%, *Cyperus bifax* with cover 1-2%, *Aristida latifolia* and *Panicum decompositum*.

This community occurred in Soil Unit 1 and 1c on the Weaber Plain.

Em7 Open Woodland of *Eucalyptus microtheca* and *Acacia ditricha* over a tall grassland dominated by *Oryza australiensis*, *Sorghum timorense* over *Panicum decompositum*.

Trees included *Eucalyptus microtheca* with cover <5% and *Bauhinia cunninghamii* with cover <2% and *Excoecaria parvifolia* with cover <1%.

Shrubs and Herbs included *Hibiscus panduriformis*, *Neptunia monosperma*, *Sesbania cannabina* and *Goodenia malvina*.

Grasses included *Sorghum timorense* with cover 15-20%, *Panicum decompositum* with cover 40-50%, *Oryza australiensis* with cover <15%, *Iseilema vaginiflorum* with cover 1-10% and *Fimbristylis laxiglumis* with cover 35%

This community occurred in Soil Unit 1 on the Weaber Plain.

Em8 Low Open Woodland of *Eucalyptus microtheca* and *Excoecaria parvifolia* over a dense grassland dominated of *Ophiuros exaltatus*, *Sorghum timorense*, *Oryza australiensis* and *Iseilema fragile*.

Trees included *Eucalyptus microtheca* with cover 2-10% and *Excoecaria parvifolia* with cover 2-10%.

Shrubs and Herbs included *Neptunia monosperma*, *Ludwigia perennis*, *Phyllanthus maderaspatensis*, *Hibiscus panduriformis*, *Alternanthera nodiflora* and *Corchorus olitorius*.

Grasses included *Ophiuros exaltatus* with cover 30-70%, *Sorghum timorense* with cover 10-30%, *Oryza australiensis*, *Iseilema fragile* and *Panicum laevinode*.

This community occurred in Soil type 5b on the Weaber Plain.

Em9 Open Woodland of *Eucalyptus microtheca* over open tussock and annual grassland of *Panicum laevinode*, *Ophiuros exaltatus*, *Cyperus conicus* and *Neptunia monosperma*

Trees included *Eucalyptus microtheca* with cover 10-30%, *Excoecaria parvifolia* with cover <5%, *Cathormion umbellatum* subsp. *moniliforme* with cover <5%.

Shrubs and Herbs included *Neptunia monosperma* with cover 15-25%, *Cyanotis axillaris* with cover <5% and *Corchorus olitorius*.

Grasses included *Panicum laevinode* with cover 10-30%, *Ophiuros exaltatus* with cover <5%, *Cyperus conicus* with cover <5%, *Aristida latifolia* with cover 5-10%, *Oryza australiensis* with cover ca. 1%.

This community occurred in Soil Unit 5a in the Weaber Plain.

Woodlands of *Eucalyptus microtheca* and *Melaleuca* spp.

EM1 Open Woodland of *Eucalyptus microtheca* over Shrubland of *Melaleuca nervosa* and *Grevillea striata* over a low open grassland of *Themeda triandra*, *Eriachne obtusa* and *Aristida hygrometrica*.

Trees included *Eucalyptus microtheca* with cover <15%, *Melaleuca nervosa* had cover <5% and *Grevillea striata* had cover <1%.

Shrubs and Herbs included *Hakea arborescens*, *Grewia retusifolia* and *Evolvulus alsinoides* var. *decumbens*.

Grasses included *Themeda triandra* with cover 50-60%, *Eriachne obtusa* had cover 5-60% and *Aristida hygrometrica* cover <5%.

This community occurred in Soil Unit 1 in Knox Creek Plain.

EM2 Woodland of *Eucalyptus microtheca* over a low woodland of *Excoecaria parvifolia*, *Melaleuca viridiflora* and *Terminalia oblongata* subsp. *volucris*.

Trees included *Adansonia gregorii*, *Acacia holosericea*, *Lophostemon lactifluus*, *Terminalia platyphylla*, *Eucalyptus microtheca*, *Excoecaria parvifolia*, *Melaleuca viridiflora* and *Terminalia oblongata* subsp. *volucris*.

Grasses included: *Themeda triandra*, *Eriachne obtusa*, *Aristida hygrometrica* and *Leptochloa neesii*.

This community occurred in Soil Unit 11 on the Knox Creek Plain along a flow line.

EM3 Woodland of *Eucalyptus microtheca*, *Melaleuca argentea* and *Lophostemon grandiflorus* subsp. *riparius* over Dense Low Woodland of *Bauhinia cunninghamii*.

Trees included *Bauhinia cunninghamii* with cover 70-100%, *Eucalyptus microtheca* with cover 10-30%, *Melaleuca argentea*, *Corymbia greeniana*, *Atalaya salicifolia*, *Cathormion umbellatum* subsp. *moniliforme*, *Corymbia bella* and *Lophostemon grandiflorus* subsp. *riparius*.

Shrubs included *Carissa lanceolata* and *Jasminum molle* with cover 2-10%, *Dodonaea platyptera*, *Celtis philippensis* and *Capparis lasiantha*.

Grasses included *Panicum mindanaense* and *Aristida latifolia*.

This community occurred in Soil Unit 7a in the Weaber Plain and was subject to regular flooding between the river bank and levee crest.

Woodlands of *Eucalyptus microtheca* and Shrubland of *Terminalia oblongata* subsp. *volucris*

ET1 Woodland of *Eucalyptus pruinosa*, *Eucalyptus microtheca* over Open Shrubland of *Terminalia oblongata* subsp. *volucris*, *Bauhinia cunninghamii* and *Carissa lanceolata* over a grassland dominated by *Themeda triandra*, *Sehima nervosum*, *Chrysopogon pallidus* and *Eriachne glauca* var. *glauca*.

Trees included *Eucalyptus microtheca*, *Melaleuca viridiflora* with cover <1%, *Terminalia oblongata* subsp. *volucris* with cover 5-10% and the mallee *Eucalyptus pruinosa* with cover <20%.

Shrubs and Herbs included *Waltheria indica* with cover <1%, *Grewia retusifolia* with cover <1%, *Neptunia monosperma*, *Hibiscus panduriformis* and *Sida spinosa*.

Grasses included *Aristida hygometrica* with cover 40-50%, *Themeda triandra* with cover 5-25%, *Sehima nervosum* with cover <10%, *Chrysopogon pallidus* with cover 5-10%, *Eriachne obtusa* with cover <10% and *Heteropogon contortus* with cover <5%.

This community occurred in Soil Unit 5e on the Knox Creek and the Keep River.

ET2 Woodland of *Eucalyptus microtheca* over *Bauhinia cunninghamii* and *Terminalia oblongata* var. *volucris* over dense grassland of *Themeda triandra* and *Sehima nervosum*.

Trees included *Eucalyptus microtheca* with cover <5%, *Bauhinia cunninghamii* with cover <5%, *Terminalia oblongata* subsp. *volucris* with cover <5%.

Shrubs and Herbs included *Carissa lanceolata*, *Dolichandrone heterophylla*, *Hakea arborescens* and *Ludwigia perennis*.

Grasses included *Themeda triandra* with cover 45%, *Sehima nervosum* with cover 20-30%. *Ophiuros exaltatus*, *Chrysopogon fallax* and *Panicum decompositum*.

This community occurred in Soil Unit 3c on the Knox Creek Plain.

ET3 Woodland of *Eucalyptus microtheca* and *Corymbia greeniana* over *Bauhinia cunninghamii*, *Terminalia oblongata* subsp. *volucris* and *Hakea arborescens* over scattered tussocks of *Aristida latifolia*.

Trees included *Eucalyptus microtheca*, *Corymbia greeniana*, *Bauhinia cunninghamii*, *Melaleuca argentea*, *Adansonia gregorii*, *Terminalia oblongata* subsp. *volucris* and *Hakea arborescens*.

Shrubs and Herbs included *Exocarpos latifolius*, *Atalaya hemiglauca*, *Grewia retusifolia*, *Phyllanthus maderaspatensis*, **Alysicarpus vaginalis* and *Hyptis suaveolens*.

Grasses included *Aristida latifolia*, *Brachyachne convergens*, *Urochloa reptans* and *Fimbristylis macrantha*.

This community occurred in Soil Unit 5a on the Keep River Plain.

ET4 Low open woodland of *Eucalyptus microtheca*, *Bauhinia cunninghamii*, over a Shrubland of *Terminalia oblongata* subsp. *volucris* over dense grassland dominated by *Themeda triandra*, *Aristida latifolia*, *Sehima nervosum*, *Chrysopogon fallax* and *Ophiuros exaltatus*.

Trees included *Bauhinia cunninghamii* with cover 2-10%, *Terminalia oblongata* subsp. *volucris* and *Acacia ditricha*.

Shrubs and annuals included *Hibiscus panduriformis*, *Dolichandrone heterophylla*, *Rhynchosia minima* and *Phyllanthus maderaspatensis*.

Grasses included *Chrysopogon fallax* and *Ophiuros exaltatus* with cover 30-70%, *Themeda triandra*, *Panicum decompositum*, *Sorghum timorense* and *Brachyachne convergens*.

This community was recorded in Soil Unit 4d on the Weaber Plain.

ET5 Open Low Woodland of *Excoecaria parvifolia*, *Bauhinia cunninghamii* over a Shrubland of *Terminalia oblongata* subsp. *volucris* and *Eucalyptus microtheca* over an Open Tussock Grassland of *Chrysopogon fallax*, *Panicum decompositum*, *Astrebla elymoides* and *Iseilema fragile*.

Trees included *Eucalyptus microtheca* and *Excoecaria parvifolia* with cover 10-30%, *Acacia ditricha* and *Bauhinia cunninghamii* with cover 2-10%, *Atalaya salicifolia* and *Terminalia oblongata* subsp. *volucris* with cover 2-10%.

Shrubs and Herbs included *Neptunia monopserma*, *Rhynchosia minima* and *Phyllanthus maderaspatensis*

Grasses included *Chrysopogon fallax* with cover 30-70%, *Sorghum timorense* with cover 30-70%, *Panicum decompositum* and *Astrebla elymoides* with cover 30-70%, *Iseilema fragile* with cover 30-70% and *Aristida latifolia*.

This community occurred in Soil Units 5b and 5bt on the Weaber Plain.

ET6 Open Low Woodland of *Excoecaria parvifolia*, *Bauhinia cunninghamii* and *Eucalyptus microtheca* over a Shrubland of *Terminalia oblongata* subsp. *volucris* and a grassland of *Panicum decompositum*, *Iseilema vaginiflorum* and *Sorghum timorense*

Trees included *Eucalyptus microtheca* with cover <5%, *Terminalia oblongata* subsp. *volucris* with cover 5-10%, *Bauhinia cunninghamii* with cover 0-3%, *Excoecaria parvifolia* with cover 5-10%.

Shrubs and annuals included *Neptunia monosperma* with cover <1%, *Stemodia tephropelina* with cover <1%, *Abelmoschus mosochatus* with cover <1%, *Wedelia asperimma* with cover <1% and *Flemingia pauciflora* with cover <5%.

Grasses included *Panicum decompositum* with cover 30%, *Aristida latifolia* with cover <5%, *Iseilema vaginiflorum* with cover <1%

This community occurred in Soil Unit 1 on the Weaber Plain.

Woodlands of *Eucalyptus miniata*

Min1 Woodland of *Eucalyptus miniata*, *Eucalyptus tetradonta* and *Terminalia* ? *platyphylla* over a shrubland of *Acacia difficilis* over an open grassland of *Aristida* sp.

Trees included *Eucalyptus miniata* with cover 15%, *Eucalyptus tetradonta* with cover <5%, *Acacia difficilis* and *Terminalia* ? *platyphylla*.

Shrubs and Herbs included *Grevillea agrifolia*, *Waltheria indica*, *Persoonia falcata* and *Spermocoe brachystema*.

Grasses included *Triodia plectrachnoides*, *Yakirra pauciflora* and *Aristida* sp.

This community occurred in the Cockatoo Soil Unit near the northern end of the Keep River Plain.

Min2 *Eucalyptus miniata* low forest over open *Grevillea agrifolia* over *Triodia acutispicula* or *Triodia burbridgeana* and *Sorghum* sp open grassland.

Trees included *Eucalyptus miniata* with cover 1-2%, *Xanthostemon paradoxus* with cover 10-12%, *Adansonia gregorii*, *Corymbia confertiflora* and *Erythrophleum chlorostachys*

Shrubs and Herbs include *Flueggea virosa* subsp. *melanthesoides*, *Calytrix exstipulata*, *Cochlospermum fraseri*, *Waltheria indica*, *Grevillea pyramidalis* and *Ptilotus spicatus*.

Grasses included *Triodia burbridgeana*, *Cyperus microcephalus*, *Triodia acutispicula* and *Sorghum* sp.

This community occurred on a moderate slope of the Cockatoo Soil Unit on the Knox Creek

Woodland of *Eucalyptus papuana*

Ep1 Woodland of *Eucalyptus papuana* over a Shrubland of *Flueggea virosa* var. *melanthesoides* over Grassland of *Heteropogon contortus*.

Trees included *Eucalyptus papuana* with cover 45-55% and *Corymbia bella*, *Acacia holosericea*.

Shrubs and Herbs included *Flueggia virosa* var. *melanthesoides* with cover 20-35%, **Calotropis procera*, *Abutilon indicum* subsp. *australiense*, **Corchorus olitorius* and *Indigofera hirsuta*.

Grasses included *Heteropogon contortus* with cover 50-60%.

This community occurred in Soil Unit 7 on a raised bank of the Keep River.

Woodland of *Eucalyptus tetrodonta*

Et1 Woodland of *Eucalyptus tetrodonta*, *Corymbia greeniana* and *Terminalia canescens* over a shrubland of *Acacia* affin. *lamprocarpa*

Trees included *Eucalyptus tetrodonta* with cover <5% and *Corymbia greeniana*.

Shrubs and Herbs included *Acacia lamprocarpa*, *Terminalia canescens* with cover 10-30%, *Grevillea refracta*, *Buchanania obovata*

Grasses included *Sorghum stipoides*, *Eriachne ciliata*, *E. melicacea* and *Heteropogon contortus*.

This community occurred in Cockatoo Soil Unit on the Keep River Plain

Woodlands of *Corymbia bella*

Cb1 Open woodland of *Eucalyptus microtheca*, *Corymbia bella*, *Corymbia greeniana*, *Excoecaria parvifolia* and *Bauhinia cunninghamii* over a grassland of *Sehima nervosum* and *Heteropogon contortus*.

Trees included *Eucalyptus microtheca* with cover 20-30%, *Corymbia bella* with cover <2%, *Excoecaria parvifolia* with cover <1% and *Bauhinia cunninghamii* with cover <1%.

Shrubs and Herbs included *Carissa lanceolata*, *Enneapogon purpureus*, *Indigofera linifolia*, *Polycarpaea corymbosa* and *Abutilon hannii*

Grasses included *Sehima nervosum* with cover 40-50%, *Heteropogon contortus* with cover 5% and *Sorghum stipoides*.

This community occurred on the edge of the Keep River in the Knox Creek Plain in Soil Units 7a and 7a/b.

Cb2 Woodland of *Eucalyptus microtheca*, *Corymbia greeniana*, *Corymbia confertiflora*, *Corymbia bella* and *Adansonia gregorii* over an open shrubland of *Bauhinia cunninghamii* and a grassland of *Sehima nervosum* and *Themeda triandra*.

Trees included *Eucalyptus microtheca* with cover 10-12%, *Corymbia greeniana* with cover 5-7%, *Corymbia confertiflora* with cover 2-3%, *Corymbia bella* with cover <2% and *Adansonia gregorii* cover <1%.

Shrubs and Herbs included *Grewia retusifolia* with <1% cover, *Indigofera linifolia*, *Goodenia sepalosa* var. *sepalosa*, *Heliotropium foveolatum* and *Uraria cylindracea*.

Grasses included *Sehima nervosum* with cover 50%, *Themeda triandra* with cover 10-15%, *Chrysopogon fallax*, *Cyperus viscidulus* and *Heteropogon contortus*.

This community occurred in Soil 7f on the Knox Creek Plain.

Cb3 Woodland of *Eucalyptus microtheca*, *Corymbia bella*, *Bauhinia cunninghamii* and *Excoecaria parvifolia* over a grassland dominated by *Ophiuros exaltatus*, *Chrysopogon fallax*, *Dichanthium sericeum* var. *polystachyum*.

Trees included *Eucalyptus microtheca* with cover 1-4%, *Corymbia bella* with cover <1%, *Bauhinia cunninghamii* with cover 2-3% and *Excoecaria parvifolia* with cover 2-3%.

Shrubs and Herbs included *Hibiscus panduriformis*, *Commelina ensifolia*, *Trichodesma zeylanicum* var. *latisepalum*, *Phyllanthus maderaspatensis* and *Alternanthera nodiflora*.

Grasses included *Ophiuros exaltatus* with cover >40%, *Chrysopogon fallax* with cover 20%, *Dichanthium sericeum* subsp. *polystachion* with cover 10-15%

This community occurred in Soil Unit 5e on the Knox Plain.

Cb4 Woodland of *Bauhinia cunninghamii*, *Eucalyptus bigalerita*, *Terminalia grandiflora* and *Corymbia bella* over an open tussock and annual grassland of *Heteropogon contortus* and *Chrysopogon fallax*.

Trees included *Bauhinia cunninghamii* with cover 10-30%, *Eucalyptus bigalerita*, *Terminalia grandiflora*, *Corymbia bella*, *Bauhinia cunninghamii*, *Adansonia gregorii* and *Hakea arborescens*.

Shrubs and Herbs included *Ficus oppositifolia*, *Phyllanthus reticulatus*, *Carissa lanceolata*, *Pterocaulon verbascifolium*, *Drosera petiolaris*, *Hybanthus enneaspermus* subsp. *enneaspermus* and *Alternanthera nodiflora*.

Grasses included *Heteropogon contortus*, *Chrysopogon fallax* with cover 10-30%, *Sorghum stipoides* with cover 2-10%, *Aristida inaequiglumis*, *A. holathera*, *Cyperus conicus* and *Eriachne obtusa*.

This community occurred in Soil Unit 8b on the Weaber Plain.

Cb5 Open Woodland of *Terminalia platyphylla*, *Corymbia bella* over an open woodland of *Bauhinia cunninghamii* and *Terminalia oblongata* subsp. *volucris* and scattered *Acacia ditricha* over a dense annual and tussock grassland of *Themeda triandra*, *Heteropogon contortus*, *Aristida latifolia*, *Ophiuros exaltatus* and *Sorghum timorense*.

Trees included *Corymbia bella* with cover 2-10%, *Terminalia platyphylla* with cover 2-10%, *Corymbia greeniana*, *Bauhinia cunninghamii* with cover <2-10% and *Terminalia oblongata* subsp. *volucris* with cover <2%.

Shrubs and Herbs included *Hibiscus panduriformis*, *Waltheria indica*, *Carissa lanceolata*, *Pterocaulon verbascifolium*

Grasses included *Themeda triandra* with cover 10-70%, *Sorghum timorense* with cover 30-70%, *Heteropogon contortus*, *Aristida latifolia* with cover 2-10% and *Ophiuros exaltatus* with cover 5-10%

This community occurred in Soil Units 4a, 4b and 4c on the Weaber Plain and Lower Keep River Plain.

Cb6 Open Woodland of *Corymbia bella*, *Corymbia polycarpa*, and *Melaleuca viridiflora* over a dense grassland of *Themeda triandra*.

Trees included *Corymbia bella*, *Corymbia polycarpa*, *Melaleuca viridiflora*, *Buchanania obovata* and *Acacia holosericea*.

Shrubs and Herbs included *Ficus oppositifolia*, *Acacia lamprocarpa* and *Opercularia* sp..

Grasses included *Themeda triandra* with cover 50-70%.

This community occurred in Soil Unit 7a on the Keep River Plain, on a gentle slope to the river.

Cb7 Open Woodland of *Corymbia bella* and *Acacia ditricha* over a Grassland of *Themeda triandra*, *Chrysopogon fallax* and *Heteropogon contortus*.

Trees included *Corymbia bella* with cover 2-10%, *Bauhinia cunninghamii* with cover <2%, *Terminalia oblongata* subsp. *volucris* with cover <1% and *Acacia ditricha* with cover <8%.

Shrubs and Herbs included *Hibiscus panduriformis* with cover <1%, *Phyllanthus maderaspatensis* with cover <1%, *Sesbania simpliciuscula* with cover <1 and *Abelmoschus moschatus* with cover <1%.

Grasses included *Chrysopogon fallax* and *Themeda triandra* with cover 30-70%, *Sorghum timorense* with cover 10-30%, *Sehima nervosum* with cover 40-50% and *Panicum decompositum*.

This community occurred in Soil Unit 1 on the Weaber Plain and Keep River Plain.

Cb8 Open Woodland of *Corymbia bella*, *Planchonia careya*, *Atalaya salicifolia* and *Acacia ditricha* over tussock grassland of *Themeda triandra*, *Ophiuros exaltatus* and *Eulalia aurea*.

Trees included *Corymbia bella*, *Bauhinia cunninghamii*, *Corymbia ferruginea*, *Planchonia careya*, *Atalaya salicifolia* and *Acacia ditricha*.

Shrubs and Herbs included *Phyllanthus maderaspatensis*, *Goodenia purpurascens* and *Ludwigia perennis*.

Grasses included *Aristida latifolia*, *Themeda triandra*, *Sehima nervosum*, *Chrysopogon fallax*, *Panicum decompositum* and *Ophiuros exaltatus*.

This community occurred in Soil Unit 8 on the Weaber Plain in a flow line at the northern tip of the Sorby Hills.

Cb9 Very Open Woodland of *Corymbia bella* over tussock and annual grassland of *Themeda triandra*, *Ophiuros exaltatus* and *Sorghum stipoides*.

Trees included *Corymbia bella* with cover 2-10%, *Bauhinia cunninghamii*, and *Atalaya salicifolia*.

Shrubs and Herbs included *Carissa lanceolata*, *Hibiscus panduriformis*, *Rhynchosia minima*, *Phyllanthus maderaspatensis*, *Sesbania simpliciuscula*, *Trichodesma zeylanicum* subsp. *latisepalum*.

Grasses included *Themeda triandra* and *Ophiuros exaltatus* with cover 30-70%, *Sorghum stipoides* with cover 30-70%, *Sehima nervosum*, *Aristida latifolia* and *Sorghum timorense*.

This community occurred in Soil Unit 9c on the Weaber Plain.

Woodlands of *Corymbia confertiflora*

Cc1 Open Woodland of *Corymbia confertiflora*, *Planchonia careya* and *Terminalia latipes* var. *latipes* over moderately dense *Bauhinia cunninghamii* and a very open tussock grassland of *Heteropogon contortus*, *Themeda triandra* and *Sorghum plumosum*.

Trees included *Corymbia bella* and *Corymbia confertiflora* with cover 2-10%, *Bauhinia cunninghamii* with cover 30-70%, *Planchonia careya*, *Terminalia latipes* var. *latipes*, *Adansonia gregorii* and *Gyrocarpus americanus*.

Shrubs and Herbs included *Grewia retusifolia*, *Walthera indica*, *Cajanus mamoratus*, *Cymbidium canaliculatum*, and *Achyranthes aspera*.

Grasses included *Heteropogon contortus* with cover 2-30%, *Sorghum plumosum* with cover 2-10% and *Aristida inaequiglumis*.

This community occurred in Soil Unit 2b on the Weaber Plain.

Cc2 Woodland of *Corymbia bella*, *Acacia ditricha*, *Corymbia confertiflora*, *Planchonia careya* and *Bauhinia cunninghamii* over an open grassland of *Themeda triandra*, *Heteropogon contortus* and *Sehima nervosum*.

Trees included *Corymbia bella* with cover <5%, *Planchonia careya* with cover 10-15%, *Corymbia confertiflora* with cover <5% *Acacia ditricha* with cover <1% and *Bauhinia cunninghamii* with cover <1%.

Shrubs and Herbs included *Ficus opposita* cover <2%, *Grewia retusifolia* with cover <1%, *Hibiscus panduriformis* and *Rhynchosia minima*.

Grasses included *Themeda triandra* with cover 15-20%, *Heteropogon contortus* with cover <90%, *Sehima nervosum* with cover 1-2%.

This community occurred in Soil Unit 4d on the Keep River Plain.

Cc3 Woodland of *Corymbia confertiflora*, *Corymbia greeniana* and *Planchonia careya* over scattered mallees of *Corymbia foelscheana* over a grassland of *Heteropogon contortus* and *Sehima nervosum*.

Trees included *Corymbia bella* with cover >10%, *Corymbia confertiflora*, *Corymbia greeniana*, *Planchonia careya* and *Corymbia foelscheana* with cover <5%.

Shrubs and Herbs included *Hibiscus panduriformis*, *Goodenia sepalosa*, *Urarua cylindracea* and *Hakea arborescens*.

Grasses included *Heteropogon contortus* and *Sehima nervosum* with cover 30-40%, *Themeda triandra* with cover <80% and *Aristida latifolia*.

This community occurred in Soil 2a on the Keep River Plain.

Cc4 Woodland of *Corymbia confertiflora*, *Eucalyptus microtheca* and *Eucalyptus tectifica* over a Grassland dominated by *Aristida holathera* var. *holathera*, *Themeda triandra*, *Sorghum plumosum* var. *plumosum*.

Trees included *Eucalyptus microtheca* with cover 5%, *Eucalyptus tectifica* with cover 5%

Shrubs and Herbs included *Acacia lamprocarpa*, *A. hemignosta*, *Terminalia canescens*, *Heliotropium foveolatum* and *Polygala eriocephala*.

Grasses included *Themeda triandra* with cover 30-40%, *Aristida holathera* var. *holathera* had cover 10%, *Dichanthium sericeum* var. *polystachyum* had cover 1-2%, *Eragrostis cumingii*, *Triodia acutispicula* and *Sorghum stipoideum*.

This community occurred in Soil Unit 8a on the Knox Creek Plain.

Woodlands of *Corymbia tectifica*

Ct1 Woodland of *Eucalyptus tectifica* over open tussock grassland of *Heteropogon contortus*, *Themeda triandra*, *Chrysopogon fallax* and *Themeda triandra*.

Trees included *Eucalyptus tectifica* with cover 10-30%, *Corymbia greeniana* with cover 10-30% and *Bauhinia cunninghamii* with cover <2%

Shrubs and Herbs included *Terminalia canescens* with cover <2%, *Indigofera hirsuta* with cover 2-10%, *Grewia retusifolia* and *Waltheria indica*.

Grasses included *Heteropogon contortus* and *Themeda triandra* with cover 10-30%, *Chrysopogon fallax*, *Eriachne obtusa* and *Aristida inaequiglumis*.

This community occurred in Soil Unit 2a and 2c on the Weaber Plain.

Ct2 Low Woodland of *Eucalyptus tectifica* over dense tussock and annual grassland of *Themeda triandra*, *Panicum decompositum* and *Sorghum timorense*.

Trees included *Eucalyptus tectifica* with cover 10-30%, *Bauhinia cunninghamii*, *Corymbia bella* and *Terminalia oblongata* subsp. *volucris*.

Shrubs and Herbs included *Neptunia monosperma*, *Hibiscus panduriformis*, *Carissa lanceolata*, *Capparis lasiantha* and *Phyllanthus reticulatus*.

Grasses included *Themeda triandra* with cover 30-70%, *Sorghum timorense* with cover 30-70%, *Chrysopogon fallax*, *Sehima nervosum* and *Sorghum plumosum*.

This community occurred in Soil Unit 4a on the Weaber Plain.

Woodlands of *Corymbia* sp., *Brachychiton diversifolius* and *Gyrocarpus americanus*

CBG Woodland of *Corymbia* spp. *Brachychiton diversifolius*, *Bauhinia cunninghamii* with scattered taller *Gyrocarpus americanus* over an open grassland of *Themeda triandra*.

Trees included *Corymbia confertiflora*, *Corymbia polycarpa*, *Atalaya hemiglauca*, *Brachychiton diversifolia*, *Bauhinia cunninghamii* and *Gyrocarpus americanus*.

Shrubs and Herbs included *Grewia retusifolia*, *Hibiscus panduriformis*, *Neptunia monosperma*, *Carissa lanceolata*, *Sesbania cannabina* and *Pterocaulon verbascifolium*

Grasses included *Themeda triandra* with cover 25%, *Sehima nervosum* with cover 1-2%, *Heteropogon contortus* with cover 2-3%, *Chrysopogon fallax* with cover <1%.

This community occurs in Soil Unit 6e on Knox Creek.

Woodland of *Bauhinia cunninghamii*

Bc1 Low Woodland of *Bauhinia cunninghamii* over tussock and annual grassland of *Iseilema* sp., *Panicum decompositum*, *Sehima nervosum*, *Aristida latifolia*, *Cyperus bifax*, *Sehima nervosum*, *Chrysopogon fallax* and *Sorghum timorense*.

Trees included *Eucalyptus microtheca* with cover <2%, *Bauhinia cunninghamii* with cover 10-30%, *Terminalia oblongata* subsp. *volucris* with cover 2-10%

Shrubs and Herbs included *Flemingia pauciflora* with cover 5-15%, *Clerodendrum floribundum*, *Hibiscus panduriformis*, *Acacia ditricha*, *Neptunia monosperma* and *Phyllanthus maderaspatensis*.

Grasses included *Sorghum timorense* with cover 10-30%, *Sehima nervosum* and *Chrysopogon fallax* with cover 30-70%, *Chionachne hubbardiana*, *Iseilema vaginiflorum* and *Sorghum stipoideum*.

Community occurred in Soil Unit 1 on the Weaber and Keep River Plains.

Bc2 Low Shrubland of *Bauhinia cunninghamii* and *Atalaya hemiglauca* over grassland of *Chrysopogon fallax* with lianes of *Rhynchosia minima*.

Trees included *Bauhinia cunninghamii* with cover 2-10%, *Terminalia oblongata* subsp. *volucris* and *Atalaya salicifolia*.

Shrubs and Herbs included *Rhynchosia minima* with cover 2-10%, *Neptunia monosperma*, *Flemingia pauciflora*, *Abelmoschus moschatus* and *Ptilotus spicatus*.

Grasses included *Chrysopogon fallax* with cover 30-70%, *Panicum decompositum*, *Aristida latifolia*, *Sorghum timorense*, *Iseilema fragile* and *Eragrostis tenellula*.

This community occurred in Soil Unit 1 on the Weaber and Knox Creek Plains.

Bc3 Low Woodland of *Bauhinia cunninghamii* occasionally with scattered *Acacia ditricha* over grassland of *Themeda triandra*, *Sehima nervosum* and *Chrysopogon fallax*.

Trees included *Bauhinia cunninghamii* with cover 5-10%, *Acacia ditricha* with cover 1-5% , *Terminalia oblongata* subsp. *volucris* with cover 1-5% and *Atalaya hemiglauca* with cover 1-5%.

Shrubs and Herbs included *Neptunia monosperma*, *Hibiscus panduriformis*, *Rhynchosia minima*, *Flemingia pauciflora* and *Capparis lasiantha*.

Grasses included *Sehima nervosum* with cover <60%, *Themeda triandra* with cover 10-90%, *Chrysopogon fallax* with cover 60-80%, *Cyperus bifax* with cover <10%, *Sorghum timorense* 10-25%.

This community occurred in Soil Unit 1 in the Keep River Plain.

Woodlands of *Excoecaria parvifolia*

Ex1 Woodland of *Excoecaria parvifolia* with scattered *Corymbia bella* and *Bauhinia cunninghamii* over mixed grass species.

Trees included *Excoecaria parvifolia* with cover 15-20%, *Corymbia bella* with cover <1%, *Bauhinia cunninghamii* with cover <5% and *Terminalia obovata* subsp. *volucris* with cover <5%.

Shrubs and Herbs included *Waltheria indica* with cover <1%, *Flueggea virrosa* with cover <2%, *Wedelia asperrima* with cover <1%.

Grasses included *Panicum trachyrhachis* with cover 40%, *Panicum decompositum* with cover 5%, *Iseilema vaginiflorum* with cover 5%, *Cyperus bifax* with cover <5%, *Aristida latifolia* with cover <5% and *Oryza australiensis* with cover <5%.

This community occurred in Soil Unit 1 on the Weaber Plain.

Ex2 Woodland of *Excoecaria parvifolia* over an open to dense grassland dominated by *Ophiuros exaltatus*, *Iseilema fragile* or *Heteropogon contortus*.

Trees included *Excoecaria parvifolia* with cover 15-20% and *Eucalyptus microtheca* with cover <1%.

Shrubs and Herbs included *Sesbania cannabina* with cover <1%, *Flemingia pauciflora* with cover <1%, *Hibiscus panduriformis* with cover <1%, *Neptunia monosperma* with cover <1%.

Grasses included *Heteropogon contortus* where dominant with cover >60%, *Iseilema fragile* where dominant with cover <90% or *Ophiuros exaltatus* where dominant with cover >60%.

Typically this community occurred along minor drainage lines within the Grasslands of the Keep River and is an extension of the grassland community G1 in Soil Unit 1.

Ex3 Woodland of *Excoecaria parvifolia* with scattered *Eucalyptus microtheca* over a Low Grassland dominated by *Sehima nervosum* and *Cyperus viscidulus*.

Trees included *Excoecaria parvifolia* with cover 40-45%, *Eucalyptus microtheca* with cover <5%.

Shrubs and Herbs included *Corchorus fascicularis* with cover <1%, *Nesaea repens* with cover <1%, *Hygrophila angustifolia* with cover <1%. *Ludwigia perennis* with cover <1% and *Aeschynomene indica* with cover <1%.

Grasses included *Sehima nervosum* with cover 50-60%, *Cyperus viscidulus* with cover <20%, *Iseilema vaginiflorum* with cover <5%, *Aristida latifolia* with cover <5%, *Panicum decompositum* with cover 1-2% and *Oryza australiensis* with cover <1%.

This community occurred in Soil unit 1e on the Knox Plain.

Ex4 Woodland of *Excoecaria parvifolia*, *Melaleuca nervosa* and *Cathormion umbellatum* subsp. *moniliforme* over scattered *Strychnos lucida* shrubs and mid-dense **Passiflora foetida* var. *hispida* lianes.

Trees included *Melaleuca nervosa*, *Excoecaria parvifolia*, *Cathormion umbellatum* subsp. *moniliforme* with patches of 90% cover, *Barringtonia acutangula* with cover >90% close to river edge.

Shrubs and Herbs included *Acacia holosericea*, *Neptunia monosperma*, *Abelmoschus moschatus*, *Hibiscus panduriformis*, *Ammania baccifera*.

Grasses included *Panicum mindanaense*, *Leptochloa neesii*, *Eriachne glauca* and *Iseilema fragile*.

This community occurred in Soil Unit 7 along the Keep River.

Woodlands of *Melaleuca* species

Me1 Woodland of *Eucalyptus* sp., *Corymbia* sp., *Terminalia grandiflora*, *Melaleuca nervosa* and *Acacia difficilis* over and open grassland of *Eriachne obtusa*, *Chrysopogon setifolius* and *Aristida holanthera* var. *holanthera*.

Trees included *Eucalyptus microtheca*, *E. tectifica*, *Corymbia confertiflora*, *Terminalia grandiflora* with cover 2-23%, and *Melaleuca nervosa*.

Shrubs and Herbs included *Cochlospermum fraseri*, *Platyzoma microphyllum*, *Buchanania obovata*, *Triodia acutispicula* and *Acacia difficilis*.

Grasses included *Eragrostis cumginii*, *Setaria apiculata*, *Yakirra pauciflora*.

This community occurred in Soil Type 8e on the Knox Creek Plain.

Me2 Low Woodland of *Melaleuca viridiflora* and *Eucalyptus tectifica* over open shrubland of *Acacia difficilis* over open grasses and sedges.

Trees included *Melaleuca viridiflora* with cover 5-10%, *Eucalyptus miniata* with cover <1%, *E. microtheca* with cover <1%.

Shrubs and Herbs included *Grevillea agrifolia* with cover 2-3%, *Acacia difficilis* with cover 2-3%, *Grewia retusifolia* with cover <5%.

Grasses included *Yakirra pauciflora*, *Schoenus punctatus*, *Aristida hygrometrica*, *Fimbristylis squarrulosa*.

This community occurred in Soil Unit 7a on the Keep River Plain.

Me3 Open shrubland of *Melaleuca acacioides* and *Excoecaria parvifolia* over scattered grassland of *Heteropogon contortus*.

Trees included *Melaleuca acacioides* with cover 5-25%, *Excoecaria parvifolia*, *Cathormion umbellatum* subsp. *moniliforme*.

Shrubs and Herbs included *Hibiscus panduriformis*, *Ammania baccifera*, *Alternanthera nodiflora*, *Flaveria australasica*.

Grasses included *Ophiuros exaltatus*, *Sporobolus australasicus*, *Chloris pumilio*, *Iseilema fragile*.

This community occurred in Soil Unit 7f on the Keep River Plain.

Me4 Woodland of *Melaleuca minutifolia*, *Melaleuca viridiflora*, *Excoecaria parvifolia*, and *Cochlospermum fraseri* over an open to dense grassland of *Themeda triandra* and *Sorghum timorense*.

Trees included *Melaleuca minutifolia* with cover 15-35%, *Melaleuca viridiflora* with cover 1-10%, *Bauhinia cunninghamii* with cover 1-2%, *Eucalyptus microtheca* with cover 1-2%, *Corymbia bella* with cover <5%, *Eucalyptus pruinosa* with cover <5%.

Shrubs and Herbs included *Cochlospermum fraseri* with cover <5%, *Dolichandrone heterophylla*, *Carissa lanceolata*, *Bergia pedicellaris*, *Waltheria indica*, *Grevillea striata*, *Polymeria calycina*, *Spermacoce auriculata*, *Abutilon hannii*, *Carissa lanceolata*, *Mimulus uvedaliae* all with cover <1%.

Grasses included *Themeda triandra* with cover 15-90%, *Sehima nervosum* with cover <15%, *Eragrostis scabra* with cover <1%, *Bulbostylis barbata* with cover <1%, *Sorghum plumosum* with cover <1%, *S. timorense* with cover <1%.

This community occurred in Soil Units 2a, 2a/3a, 3a/4a on the Keep River Plain.

Woodland of *Buchanania obovata*

Bo1 Low Woodland of *Buchanania obovata* and *Bauhinia cunninghamii* over Open Grassland of *Sehima nervosum* and *Sorghum stipoides*.

Trees included *Buchanania obovata*, *Bauhinia cunninghamii* with cover 10-30%, *Adansonia gregorii*, *Grevillea pyramidalis*, *Corymbia confertiflora*.

Shrubs and Herbs included *Hibiscus panduriformis*, *Exocarpos latifolius*, *Waltheria indica*, *Grewia retusifolia*, *Rhynchosia minima*, *Phyllanthus maderaspatensis*.

Grasses included *Sehima nervosum* with cover 10-30%, *Sorghum stipoides* with cover 10-30%, *Eragrostis elongata*, *Panicum mindanaense*.

This community occurred in small pockets of soil amongst dolomite blocks on a Dolomite Hill in the Weaber Plain

Woodlands of *Terminalia canescens*

Tc1 Low Woodland of *Terminalia canescens* over a very open *Heteropogon contortus* grassland.

Trees included *Terminalia canescens* with cover 10-15%, *Cochlospermum fraseri* with cover 2-3%, *Ventilago viminalis* with cover 1-2%, *Atalaya hemiglauca*, *Grevillea pyramidalis*, *Strychnos lucida*.

Shrubs and Herbs included *Owenia vernicosa*, *Flueggea virosa* subsp. *melanthesoides*, *Capparis lasiantha*

Grasses included *Sehima nervosum*, *Sorghum* sp., *Enneapogon purpurescens*.

This community occurred on a Sandstone Hill on the Knox Creek Plain.

Attachment B

**A Fauna survey of the M2 Development Area
of the Ord River Irrigation Scheme**

**ORD RIVER IRRIGATION
AREA STAGE 2
PROPOSED DEVELOPMENT
OF THE M2 AREA**

**A Fauna survey of the M2
Development Area of the Ord
River Irrigation Scheme**

Prepared for:

**WESFARMERS LIMITED,
MARUBENI CORPORATION AND THE WATER
CORPORATION OF WESTERN AUSTRALIA**
Level 7, 40 The Esplanade
Perth WA 6000

Prepared by:

**Dr Ray Hart for
Kinhill Pty Ltd**
ACN 007 660 317
47 Burswood Road, Victoria Park WA 6100
Telephone 08 9362 5900, Facsimile 08 9362 5627

October 1999

CONTENTS

Section	Page
1 SUMMARY	
2 INTRODUCTION	
3 METHODS	
4 RESULTS	
4.1 Survey Results	4-4
4.2 Conservation Status of Species	4-7
5 REFERENCES	

Appendix 1 - Locations and descriptions of the Study Sites

Appendix 2 - List of vertebrates species except bats which may occur or were recorded, except for predominately aquatic species

1 Summary

A survey of the vertebrate fauna of the black soil of the M2 Development Area of the Ord River Irrigation Scheme was carried out in June 1999 to supplement a previous survey. Pit and Elliott trapping was used at six sites, two in each of the Weaber, Knox Creek and Keep River plains, and birds were recorded opportunistically.

The survey recorded four species of frogs, 12 species of lizards, six species of snakes, 48 species of birds and three species of small mammals. This is a relatively small fraction of the species which may occur in the area, but a significant part of the common species. The numbers were limited by the early dry season timing, and the short duration of the trapping programme. The black soil plain areas are not rich in species or individuals. Small mammals are particularly limited, with only two species widespread and common. The black soil plain environment is harsh for fauna, with limited structural diversity in the vegetation, a single soil type, prolonged flooding in summer, and dry conditions in winter coupled with hard-setting soils.

The numbers of species and individuals caught by the trapping are too small to make any useful statements about the variations between sites except that frogs were most common in the wettest site. There is very limited variation between the sites in terms of habitat features for fauna, and it is not surprising that there are no obvious differences.

The survey did not locate *Ctenotus rimacola* which has recently been described as a black soil plain endemic, although this species is not thought to be rare.

At least five of the reptile species collected are undescribed species, but this high number of undescribed species is the result of limited collecting in this environment and the region in general rather than any concentration of rare species. There is also doubt about the identification of some of the small mammals and further taxonomic work needs to be carried out.

A list of the vertebrate fauna species which might be present is given. Although a large fauna is probably present there are few rare species.

On the basis of rare species it is unlikely that the proposed development would have a significant impact.

2 Introduction

A previous survey of the vertebrate fauna was undertaken by Ecologia Environmental Consultants in October 1996 and February 1998. These surveys covered a larger area than that proposed for development, with limited trapping on the black soil plains that would be the focus of development. Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia therefore commissioned an additional survey of the black soil plain areas in June 1999 and this latter survey is the subject of this report.

3 Methods

Six sites were surveyed, with two in each of the Weaber, Knox Creek and Keep River plains. The sites were selected to cover the geographic range of the study area and the range of variation within the black soil plains. The sites are described in Appendix 1, and can be summarised as:

- Site 1: Open woodland including *Eucalyptus microtheca* over dense short grasses.
- Site 2: Woodland of mixed trees over dense short grasses, and slightly damper than site 1.
- Site 4: Woodland of mixed trees over tall grasses in a relatively wet site.
- Site 5: Scattered trees over dense short grasses.
- Site 7: Open woodland over dense short grasses.
- Site 8: Scattered trees including *Eucalyptus microtheca* over tall grasses, and slightly damper than site 7.

Lines of eight pit traps of 20 litre buckets were set in a drift fence of 50m, and 10 Elliott traps were used at each site, except for Site 4 where only 5 Elliott traps were used. The Elliott traps were particularly aimed at rats and mice. The pit traps were not baited, but the Elliott traps were baited with oats, peanut paste and fish.

The traps were run between the 7 – 12 of June 1999 for five nights at Sites 7 and 8, four nights at Sites 1, 2 and 5, and two nights at Site 4. The weather was warm throughout the trapping time.

Other species were recorded opportunistically during the day and night, including road kills and any calls or other signs which could be identified.

4 Results

4.1 SURVEY RESULTS

The survey was carried out at a time when the ground was just drying out after a prolonged wet season. The weather was warm and with no rain, so that the soil was drying out rapidly. A tractor-mounted auger was necessary to excavate holes for the pit traps.

The species and individuals caught in the traps or nearby are listed in Table 1, along with other records from black soil areas but not near a trapping site.

In addition to the results given in Table 1, the dragon lizard *Diporiphora magna* was found near the Keep River, but not strictly on black soil.

Searching at night produced only large numbers of frogs that were difficult to catch because they were in cracks in the soil, but most were the same species listed in Table 1.

Birds were recorded opportunistically, and the species identified are listed in Table 2.

Vertebrate species excepting bats that could be expected to occur on the black soil plains are listed in Appendix 2. Aquatic species, more typical of rivers, pools and wet sites within the black soil were also not sampled. Appendix 2 provides a full taxonomic list of the species.

Table 1 Individuals caught at the trapping sites or nearby

Species	Trapping sites						
	1	2	4	5	7	8	Other
<i>Limnodynastes convexiusculus</i>						7	2
<i>Limnodynastes tasmaniensis</i> *	3	3		1		3	4
<i>Litoria inermis</i>						1	
<i>Litoria nasuta</i>	1					8	10
<i>Heteronotia binoei</i>	2			1	2		
<i>Delma</i> aff. <i>tincta</i>	1						
<i>Gemmatophora gilberti</i>	6				3	3	
<i>Carlia munda</i>	3			2			
<i>Cryptoblepharus</i> aff. <i>carabyi</i>						6	
<i>Cryptoblepharus</i> aff. <i>plagiocephalus</i>				1			
<i>Ctenotus robustus</i>	1			1			
<i>Menetia</i> aff. <i>greyii</i>	5			1	5	1	
<i>Tiliqua scincoides</i>							1
<i>Varanus panoptes</i>							2
<i>Varanus scalaris</i> *	2					2	
<i>Ramphotyphlops ligatus</i>		1		1	2		

Table 1 Individuals caught at the trapping sites or nearby (continued)

Species	Trapping sites						
	1	2	4	5	7	8	Other
Ramphotyphlops sp. 2 *	1						
Acanthophis praelongus	1						
Demansia sp. ?simplex *		1					
Furina aff. ornata	1						
Pseudechis australis							1
Planigale ingrami	2	1		1		1	
Planigale maculata *		2				1	
Leggadina lakedownensis				1			

* species not recorded in Ecologia Environmental Consultants (1997) surveys.

Table 2 Species of birds observed within the study area

Species	Common Name
ARDEIDAE	
Ephippiorhynchus asiaticus *	Jabiru
Ardea pacifica	White-necked Heron
Egretta garzetta	Little Egret
Nycticorax caledonicus	Nankeen Night Heron
THRESKIORNITHIDAE	
Threskiornis molucca	Australian White Ibis
ACCIPITRIDAE	
Hamirostra melanosternon	Black-breasted Buzzard
Milvus migrans	Black Kite
Haliastur spheurnus	Whistling Kite
Circus assimilis	Spotted Harrier
Aquila audax	Wedge-tailed Eagle
Hieraaetus morphnoides	Little Eagle
FALCONIDAE	
Falco berigora	Brown Falcon
Falco cenchroides	Nankeen Kestrel
GRUIDAE	
Grus rubicunda	Brolga
OTIDIDAE	
Ardeotis australis	Australian Bustard
BURHINIDAE	
Burhinus grallarius	Bush Stone-curlew
COLUMBIDAE	
Ocyphaps lophotes	Crested Pigeon
Geopelia striata	Peaceful Dove
Geopelia humeratus	Bar-shouldered Dove

Table 2 Species of birds observed within the study area (continued)

Species	Common Name
CACATUIDAE	
<i>Calyptorhynchus banksii</i>	Red-tailed Black-Cockatoo
<i>Cacatua roseicapilla</i>	Galah
<i>Cacatua sanguinea</i>	Little Corella
<i>Nymphicus hollandicus</i>	Cockatiel
PSITTACIDAE	
<i>Trichoglossus haematodus</i>	Rainbow Lorikeet
<i>Aprosmictus erythropterus</i>	Red-winged Parrot
<i>Melopsittacus undulatus</i>	Budgerigar
STRIGIDAE	
<i>Ninox novaeseelandiae</i>	Southern Boobook
TYTONIDAE	
<i>Tyto alba</i>	Barn Owl
PODARGIDAE	
<i>Podargus strigoides</i>	Tawny Frogmouth
CAPRIMULGIDAE	
<i>Eurostopodus argus</i>	Spotted Nightjar
HALCYONIDAE	
<i>Dacelo leachii</i>	Blue-winged Kookaburra
<i>Todiramphus pyrrophygia</i>	Red-backed Kingfisher
MEROPIDAE	
<i>Merops ornatus</i>	Rainbow Bee-eater
PARDALOTIDAE	
<i>Pardalotus striatus</i>	Striated Pardalote
MELIPHAGIDAE	
<i>Lichmera indistincta</i>	Brown Honeyeater
POMATOSTOMIDAE	
<i>Pomatostomus temporalis</i>	Grey-crowned Babbler
DICRURIDAE	
<i>Grallina cyanoleuca</i>	Magpie-lark
<i>Rhipidura leucophrys</i>	Willie Wagtail
CAMPEPHAGIDAE	
<i>Coracina novaehollandiae</i>	Black-faced Cuckoo-shrike
<i>Lalage sueurii</i>	White-winged Triller
ARTAMIDAE	
<i>Artamus cinereus</i>	Black-faced Woodswallow
<i>Cracticus nigrogularis</i>	Pied Butcherbird
<i>Gymnorhina tibicen</i>	Australian Magpie
CORVIDAE	
<i>Corvus orru</i>	Torresian Crow
ALAUDIDAE	
<i>Mirafrja javanica</i>	Singing Bushlark
HIRUNDINIDAE	
<i>Hirundo ariel</i>	Fairy Martin
SYLVIIDAE	
<i>Cinclorhamphus mathewsi</i>	Rufous Songlark
<i>Cisticola exilis</i>	Golden-headed Cisticola

* not recorded in Ecologia Environmental Consultants (1997) survey

4.2 CONSERVATION STATUS OF SPECIES

The following species have a recognised conservation status:

Schedule 1 of the Wildlife Act as “Rare or likely to become extinct”.

Gouldian Finch (*Erythrura gouldiae*). Discussed in Ecologia Environmental Consultants 1997 report.

Schedule 4 of the Wildlife Act as “In need of special protection”.

The Peregrine Falcon (*Falco peregrinus*), which is a widespread although uncommon species which is threatened by egg-shell thinning due to pesticides, illegal hunting as a pest, and capture for falconry and the cage trade. Pesticides are a problem in only restricted areas and in Western Australia this species is regarded as uncommon but secure.

In addition to these species which have a formal gazetted conservation status, the Department of Conservation and Land Management also maintains a Priority list of species which are restricted, vulnerable or too poorly known to be considered for gazetting. These species have no special protection, but their presence is normally considered.

The Priority list species which might occur are:

Priority 3

- Brush-tailed Phascogale (*Phascogale tapoatafa*) which is widespread across northern Australia but poorly known. It is apparently sparsely distributed and possibly vulnerable. It is also present in the south where it has declined greatly and is regarded as very vulnerable.

Priority 4

- The Square-tailed Kite (*Lophoictinia isura*) which occurs widely across most of Australia except the driest regions. It prefers woodland areas but can be found in almost any habitat. This species is scarce but widespread and would not be threatened by the loss of small areas of habitat.
- The Grey Falcon (*Falco hypoleucos*) which occurs widely from the northern half of Western Australia across into south-eastern and eastern Australia. It occurs in a variety of mainly open habitats. It is rare everywhere and subject to great fluctuations, but it is widespread and does not appear to have declined. Again it would not be threatened by the loss of small areas of habitat.
- The Bush Stone-Curlew (*Burhinus grallarius*) which is widespread over much of Australia although it has declined greatly in more settled areas and may have been affected by fox predation in southern areas. It prefers woodland with grass but can be found in a variety of habitats. It is present on the areas considered as a resident species, and was recorded in the present survey. It is potentially threatened in southern areas but is probably secure in the north.
- Lakeland Downs Mouse (*Leggadina lakedownensis*) which occurs in disjunct populations in the Pilbara and Kimberleys but its status is uncertain. While apparently rare this species is now known to be widespread in northern Australia and it may turn out to be

poorly collected rather than rare due to the limited collecting which has been carried out regionally.

Priority 3 species are defined as “Taxa with several, poorly known populations, some on conservation lands. Taxa which are known from few specimens or sight records from one or a few localities, some of which are on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna”.

Priority 4 species are defined as “Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands”.

DISCUSSION

The survey produced four species of frogs, 12 species of lizards, six species of snakes, 48 species of birds and three species of small mammals. This is a relatively small fraction of the species which may occur in the area, but a significant part of the common species. The numbers were limited by the early dry season timing, and the short duration of the trapping programme. The black soil plain areas are not rich in species or individuals. Small mammals are particularly limited, with only two species widespread and common. The black soil plain environment is harsh for fauna, with limited structural diversity in the vegetation, a single soil type, prolonged flooding in summer, and dry conditions in winter coupled with hard-setting soils.

The numbers of species and individuals caught by the trapping are too small to make any useful statements about the variations between sites. The only obvious feature is the high number of frogs at Site 8 which was the wettest site pit trapped. There is very limited variation between the sites in terms of habitat features for fauna, and it is not surprising that there are no obvious differences.

Five of the species recorded in the June survey, as indicated in Tables 1 and 2, were not recorded in the Ecologia Environmental Consultants (1997) surveys. The June survey did not record *Ctenotus rimacola* which has recently been described as a black soil plain endemic (Horner and Fisher 1998) and which was listed in the Ecologia Environmental Consultants (1997) as *Ctenotus ? joanae*. Two specimens of the sibling species *Ctenotus robustus* (from which *Ctenotus rimacola* was separated) were caught. These results suggest that *Ctenotus rimacola* is possibly not a common species.

At least five of the species collected (the species of *Delma*, both species of *Cryptoblepharus*, the species of *Menetia*, and the species of *Furina*) are undescribed species. These are known to be different, and this high number of undescribed species is the result of limited collecting in this environment and the region in general rather than a concentration of rare species. There is also doubt about the identification of the Planigales and further work will be carried out by the W.A. Museum.

On the basis of rare species it is unlikely that the proposed development will have a significant impact.

5 REFERENCES

Horner, P. and A. Fisher (1998). *Ctenotus rimacola* sp. nov. (Scincidae), a new species of lizard with two allopatric subspecies, from the Ord-Victoria region of northwestern Australia. Records of the Western Australian Museum 19, 187-200.

Ecologia Environmental Consultants (1997) Ord River Irrigation Area - Stage M2 Development Area Terrestrial Biological Assessment. Unpublished report for Department of Resources Development, Perth.

APPENDIX 1

LOCATIONS AND DESCRIPTIONS OF THE STUDY SITES

Site 1: Knox Plain

0498221; 827 6512

Open Woodland of *Eucalyptus microtheca* and *Excoecaria parvifolia* over Grassland dominated by *Aristida latifolia*, *Panicum decompositum* and *Iseilema vaginiflorum*.

<i>Eucalyptus microtheca</i>	600-1200cm	5%
<i>Excoecaria parvifolia</i>	300-600 cm	15%
<i>Terminalia oblongata</i> ssp. <i>volucris</i>	150-300cm	1%
<i>Iseilema vaginiflorum</i>	120cm	15%
<i>Aristida latifolia</i>	150cm	50%
<i>Panicum decompositum</i>	120cm	5%

Site 2: Knox Plain

0498726; 8291463

Woodland of *Eucalyptus microtheca*, *Terminalia oblongata* ssp. *volucris* and *Atalaya hemiglauc*a and *Acacia ditricha* over Grassland dominated by *Panicum decompositum*, *Aristida latifolia* and *Iseilema vaginiflorum*.

<i>Terminalia oblongata</i> ssp. <i>volucris</i>	400cm	15%
<i>Atalaya hemiglauc</i> a	200-800cm	5%
<i>Eucalyptus microtheca</i>	600-1200cm	5%
<i>Acacia ditricha</i>	200-450cm	1.5%
<i>Panicum decompositum</i>	80cm	60%
<i>Aristida latifolia</i>	150cm	5%
<i>Iseilema vaginiflorum</i>	80cm	5%
Herbs	120cm	5%

Site 4: Keep Plain

0510139; 8297462

Woodland of *Bauhinia cunninghamii*, *Terminalia oblongata* ssp. *volucris*, *Acacia ditricha*, *Excoecaria parvifolia* and *Atalaya hemiglauc*a over Tall Grassland dominated by *Ophiuros exaltatus*, *Sorghum timorense* and *Iseilema vaginiflorum*.

<i>Bauhinia cunninghamii</i>	350-900cm	15%
<i>Terminalia oblongata</i> ssp. <i>volucris</i>	300-600cm	5%
<i>Atalaya hemiglauc</i> a	200-600cm	5%
<i>Acacia bidwillii</i>	200-600cm	15%

<i>Excoecaria parvifolia</i>	200-600cm	5%
<i>Ophiuros exaltatus</i>	250cm	20%
<i>Sorghum timorense</i>	350cm	20%
<i>Iseilema vaginiflorum</i>	150cm	15%
<i>Dichanthium sericeum</i>	150cm	30%
<i>Chionachne hubbardiana</i>	120cm	5%

Site 5: Keep Plain

0512806; 8302302

Grassland dominated by *Themeda triandra* and *Aristida latifolia* with emergent trees of *Acacia ditricha* and *Bauhinia cunninghamii*.

<i>Acacia ditricha</i>	100-400cm	2%
<i>Bauhinia cunninghamii</i>	200-400cm	8%
<i>Themeda triandra</i>	150cm	30%
<i>Aristida latifolia</i>	80cm	40%
<i>Sorghum timorense</i>	150cm	5%
Herbs	120cm	2%

Site 7: Weaber Plain

0495013; 8295571

Open Woodland of *Bauhinia cunninghamii* and *Terminalia oblongata* ssp. *volucris* over grassland dominated by *Aristida latifolia*.

<i>Bauhinia cunninghamii</i>	300-800cm	15%
<i>Terminalia oblongata</i> ssp. <i>volucris</i>	400cm	10%
<i>Acacia ditricha</i>	200-600cm	2%
<i>Aristida latifolia</i>	100cm	85%
<i>Panicum decompositum</i>	60cm	5%
<i>Flemingia pauciflora</i>	20cm	5%
<i>Sehima nervosum</i>	80cm	8%
Herbs		1%

Site 8: Weaber Plain

0489154; 8294255

Tall Grassland dominated by *Oryza australiensis* with emergent *Eucalyptus microtheca* and *Excoecaria parvifolia*.

<i>Eucalyptus microtheca</i>	600-1200cm	5%
<i>Excoecaria parvifolia</i>	300cm	3%
<i>Oryza australiensis</i>	300cm	55%
<i>Ophiuros exaltatus</i>	300cm	15%
<i>Sorghum timorense</i>	400cm	25%
Herbs		2%

APPENDIX 2
LIST OF VERTEBRATE SPECIES EXCEPT BATS
WHICH MAY OCCUR OR WHICH WERE RECORDED,
EXCEPT FOR PREDOMINANTLY AQUATIC SPECIES

INTRODUCED SPECIES ARE IDENTIFIED BY AN ASTERISK (*)

Species	Common Name
FROGS	
LEPTODACTYLIDAE	
<i>Limnodynastes convexiusculus</i>	Marbled Frog
<i>Limnodynastes tasmaniensis</i>	Spotted Grass Frog
<i>Uperoleia trachyderma</i>	Blacksoil Toadlet
HYLIDAE	
<i>Cyclorana australis</i>	Giant Frog
<i>Cyclorana cryptotis</i>	Hidden-ear Frog
<i>Cyclorana cultripes</i>	Knife-footed Frog
<i>Cyclorana vagitus</i>	Wailing Frog
<i>Litoria inermis</i>	Peter's Frog
<i>Litoria nasuta</i>	Rocket Frog
<i>Litoria pallida</i>	Pale Frog
<i>Litoria rubella</i>	Red Tree Frog
<i>Litoria wotjulumensis</i>	Wotjulum Frog
REPTILES	
GEKKONIDAE	
<i>Diplodactylus stenodactylus</i>	Widespread Gecko
<i>Gehyra australis</i>	Top-end Dtella
<i>Heteronotia binoei</i>	Binoe's Prickly Gecko
<i>Oedura rhombifera</i>	Zig-zag Gecko
<i>Strophurus ciliaris ciliaris</i>	Spiny-tailed Gecko
PYGOPODIDAE	
<i>Delma borea</i>	Northern Delma
<i>Delma aff. tincta</i>	
<i>Lialis burtonis</i>	Burton's Legless Lizard
<i>Pygopus nigriceps schraderi</i>	Schrader's Scaly-foot
AGAMIDAE	
<i>Chelosania brunnea</i>	Chameleon Dragon
<i>Chlamydosaurus kingii</i>	Frilled Lizard
<i>Gemmatophora gilberti gilberti</i>	Gilbert's Arboreal Dragon
<i>Tympanocryptis lineata macra</i>	Blacksoil Earless Dragon
SCINCIDAE	
<i>Carlia munda</i>	Neat Carlia
<i>Cryptoblepharus aff. carnabyi</i>	
<i>Cryptoblepharus aff. plagiocephalus</i>	
<i>Ctenotus militaris</i>	Military Ctenotus
<i>Ctenotus pantherinus acripes</i>	Spiny-footed Leopard Ctenotus
<i>Ctenotus rimacola camptris</i>	Western Black Soil Ctenotus
<i>Ctenotus robustus</i>	Robust Ctenotus
<i>Glaphyromorphus isolepis</i>	Northern Bar-lipped Skink
<i>Menetia aff. greyii</i>	
<i>Proablepharus tenuis</i>	Northern Pygmy Skink
<i>Tiliqua scincoides intermedia</i>	Northern Bluetongue

Species	Common Name
VARANIDAE	
<i>Varanus panoptes panoptes</i>	Northern Yellow-spotted Monitor
<i>Varanus scalaris</i>	Spotted Tree Monitor
<i>Varanus storri ocreatus</i>	Rusty Ground Monitor
<i>Varanus tristis</i>	Black-tailed Monitor
TYPHLOPIDAE	
<i>Ramphotyphlops diversus diversus</i>	Northern Blind Snake
<i>Ramphotyphlops guentheri</i>	Guenther's Blind Snake
<i>Ramphotyphlops ligatus</i>	Robust Blind Snake
<i>Ramphotyphlops unguirostris</i>	Claw-beaked Blind Snake
BOIDAE	
<i>Antaresia childreni</i>	Children's Python
<i>Aspidites melanocephalus</i>	Black-headed Python
<i>Liasis olivaceus olivaceus</i>	Olive Python
COLUBRIDAE	
<i>Boiga fusca ornata</i>	Northern Brown Tree Snake
<i>Dendrelaphis punctulatus</i>	Common Tree Snake
<i>Styporhynchus mairii</i>	Mair's Keelback
ELAPIDAE	
<i>Acanthophis praelongus</i>	Northern Death Adder
<i>Demansia atra</i>	Black Whip Snake
<i>Demansia olivacea</i>	Olive Whip Snake
<i>Furina aff. ornata</i>	
<i>Pseudechis australis</i>	Mulga Snake
<i>Pseudonaja ingrami</i>	Ingram's Brown Snake
<i>Pseudonaja modesta</i>	Ringed Brown Snake
<i>Pseudonaja nuchalis</i>	Gwardar
<i>Rhinoplocephalus pallidiceps</i>	Northern Small-eyed Snake
<i>Simoselaps roperi</i>	Northern Shovel-nosed Snake
<i>Suta ordensis</i>	Ord Curl Snake
<i>Vermicella multifasciata</i>	Many-ringed Bandy Bandy
BIRDS	
CASUARIIDAE	
<i>Dromaius novaehollandiae</i>	Emu
PHASIANIDAE	
<i>Coturnix ypsilophora</i>	Brown Quail
ACCIPITRIDAE	
<i>Elanus axillaris</i>	Black-shouldered Kite
<i>Lophoictinia isura</i>	Square-tailed Kite
<i>Hamirostra melanosternon</i>	Black-breasted Buzzard
<i>Milvus migrans</i>	Black Kite
<i>Haliastur sphenurus</i>	Whistling Kite
<i>Circus assimilis</i>	Spotted Harrier

Species	Common Name
<i>Accipiter fasciatus</i>	Brown Goshawk
<i>Accipiter cirrhocephalus</i>	Collared Sparrowhawk
<i>Haliaeetus leucogaster</i>	White-breasted Sea-eagle
<i>Aquila audax</i>	Wedge-tailed Eagle
<i>Hieraaetus morphnoides</i>	Little Eagle
FALCONIDAE	
<i>Falco berigora</i>	Brown Falcon
<i>Falco longipennis</i>	Australian Hobby
<i>Falco hypoleucos</i>	Grey Falcon
<i>Falco peregrinus</i>	Peregrine Falcon
<i>Falco cenchroides</i>	Nankeen Kestrel
GRUIDAE	
<i>Grus rubicunda</i>	Brolga
OTIDIDAE	
<i>Ardeotis australis</i>	Australian Bustard
TURNICIDAE	
<i>Turnix velox</i>	Little Button-quail
<i>Turnix pyrrhothorax</i>	Red-chested Button-quail
BURHINIDAE	
<i>Burhinus grallarius</i>	Bush Stone-curlew
CHARADRIIDAE	
<i>Elsayornis melanops</i>	Black-fronted Dotterel
<i>Vanellus miles</i>	Masked Lapwing
GLAREOLIDAE	
<i>Glareola maldivarum</i>	Oriental Pratincole
<i>Stiltia isabella</i>	Australian Pratincole
COLUMBIDAE	
<i>Phaps chalcoptera</i>	Common Bronzewing
<i>Ocyphaps lophotes</i>	Crested Pigeon
<i>Geopelia cuneata</i>	Diamond Dove
<i>Geopelia striata</i>	Peaceful Dove
<i>Geopelia humeratus</i>	Bar-shouldered Dove
CACATUIDAE	
<i>Calyptorhynchus banksii banksii</i>	Red-tailed Black-Cockatoo
<i>Cacatua roseicapilla</i>	Galah
<i>Cacatua sanguinea</i>	Little Corella
<i>Nymphicus hollandicus</i>	Cockatiel
PSITTACIDAE	
<i>Trichoglossus haematodus rubritorquis</i>	Rainbow Lorikeet

Species	Common Name
<i>Psitteuteles versicolor</i>	Varied Lorikeet
<i>Aprosmictus erythropterus</i>	Red-winged Parrot
<i>Platycercus venustus</i>	Northern Rosella
<i>Melopsittacus undulatus</i>	Budgerigar
CUCULIDAE	
<i>Cuculus pallidus</i>	Pallid Cuckoo
<i>Chrysococcyx osculans</i>	Black-eared Cuckoo
<i>Chrysococcyx basalis</i>	Horsfield's Bronze-Cuckoo
<i>Scythrops novaehollandiae</i>	Channel-billed Cuckoo
STRIGIDAE	
<i>Ninox novaeseelandiae</i>	Southern Boobook
TYTONIDAE	
<i>Tyto alba</i>	Barn Owl
PODARGIDAE	
<i>Podargus strigoides</i>	Tawny Frogmouth
CAPRIMULGIDAE	
<i>Eurostopodus argus</i>	Spotted Nightjar
AEGOTHELIDAE	
<i>Aegotheles cristatus</i>	Australian Owlet-nightjar
APODIDAE	
<i>Apus pacificus</i>	Fork-tailed Swift
HALCYONIDAE	
<i>Dacelo leachii</i>	Blue-winged Kookaburra
<i>Todiramphus pyrrhopygia</i>	Red-backed Kingfisher
<i>Todiramphus sanctus</i>	Sacred Kingfisher
MEROPIDAE	
<i>Merops ornatus</i>	Rainbow Bee-eater
CORACIIDAE	
<i>Eurystomus orientalis</i>	Dollarbird
MALURIDAE	
<i>Malurus melanocephalus</i>	Red-backed Fairy-wren
PARDALOTIDAE	
<i>Pardalotus rubricatus</i>	Red-browed Pardalote
<i>Pardalotus striatus</i>	Striated Pardalote
ACANTHIZIDAE	
<i>Smicronis brevirostris</i>	Weebill

Species	Common Name
MELIPHAGIDAE	
Philemon citreogularis	Little Friarbird
Entomyzon cyanotis	Blue-faced Honeyeater
Manorina flavigula	Yellow-throated Miner
Lichenostomus plumulus	Grey-fronted Honeyeater
Lichenostomus flavescens	Yellow-tinted Honeyeater
Melithreptus gularis	Black-chinned Honeyeater
Lichmera indistincta	Brown Honeyeater
Ephthianura crocea	Yellow Chat
PETROICIDAE	
Melanodryas cucullata	Hooded Robin
POMATOSTOMIDAE	
Pomatostomus temporalis	Grey-crowned Babbler
PACHYCEPHALIDAE	
Pachycephala rufiventris	Rufous Whistler
Colluricincla harmonica	Grey Shrike-thrush
DICRURIDAE	
Myiagra inquieta	Restless Flycatcher
Grallina cyanoleuca	Magpie-lark
Rhipidura leucophrys	Willie Wagtail
CAMPEPHAGIDAE	
Coracina novaehollandiae	Black-faced Cuckoo-shrike
Coracina maxima	Ground Cuckoo-shrike
Lalage sueurii	White-winged Triller
ORIOOLIDAE	
Oriolus sagittatus	Olive-backed Oriole
ARTAMIDAE	
Artamus leucorhynchus	White-breasted Woodswallow
Artamus personatus	Masked Woodswallow
Artamus superciliosus	White-browed Woodswallow
Artamus cinereus	Black-faced Woodswallow
Cracticus torquatus	Grey Butcherbird
Cracticus nigrogularis	Pied Butcherbird
Gymnorhina tibicen	Australian Magpie
CORVIDAE	
Corvus orru	Torresian Crow
PTILONORHYNCHIDAE	
Chlamydera nuchalis	Great Bowerbird

Species	Common Name
ALAUDIDAE	
Mirafra javanica	Singing Bushlark
MOTACILLIDAE	
Anthus novaeseelandiae	Richard's Pipit
Motacilla flava	Yellow Wagtail
PASSERIDAE	
Taeniopygia bichenovii	Double-barred Finch
Poephila acuticauda	Long-tailed Finch
Poephila personata	Masked Finch
Neochmia ruficauda	Star Finch
Erythrura gouldiae	Gouldian Finch
DICAEIDAE	
Dicaeum hirundinaceum	Mistletoebird
HIRUNDINIDAE	
Hirundo rustica	Barn Swallow
Hirundo nigricans	Tree Martin
Hirundo ariel	Fairy Martin
SYLVIIDAE	
Cinclorhamphus mathewsi	Rufous Songlark
Cisticola exilis	Golden-headed Cisticola
MAMMALS	
DASYURIDAE	
Dasyurus hallucatus	Northern Quoll
Planigale ingrami subtilissima	Long-tailed Planigale
Planigale maculata maculata	Common Planigale
Phascogale tapoatafa pirata	Brush-tailed Phascogale
MACROPODIDAE	
Macropus agilis nigrescens	Agile Wallaby
Macropus antilopinus	Antilopine Wallaroo
Macropus robustus	Euro
Onychogalea unguifera	Northern Nailtail Wallaby
MURIDAE	
Leggadina lakedownensis	Lakeland Downs Mouse
Pseudomys delicatulus	Delicate Mouse
* Mus musculus	House Mouse
Rattus colletti	Dusky Rat
Rattus villosissimus	Long-haired Rat

Species	Common Name
CANIDAE	
* Canis lupus dingo	Dingo
FELIDAE	
* Felis catus	Feral Cat
EQUIDAE	
* Equus asinus	Donkey

Attachment C

**A SURVEY OF BATS FOR THE
ORD RIVER IRRIGATION AREA STAGE 2**

A Survey of Bats for the Ord River Irrigation Area Stage 2 Project

A report to Kinhill Pty Ltd



Ghost Bat Macroderma gigas

Lindy Lumsden¹ and Sue Churchill²

¹ Arthur Rylah Institute for Environmental Research,
Department of Natural Resources and Environment,
123 Brown St, Heidelberg, Vic 3084

² 26 Riverview Drive, Paradise, SA 5075

July 1999

Table of Contents

Introduction	2
Methods	2
Study area	2
Survey methods	3
Limitations of survey	6
Results	7
Annotated species list	11
Discussion	19
Effect of clearing on bat populations	19
Suggestions for monitoring and further work	19
Acknowledgments	20
References	20
Appendix 1. Reference calls taken from individuals caught during the survey of the Ord Stage 2 survey	21

List of Tables

Table 1. Location and habitat of sites used to survey bats.....	2
Table 2. The amount of survey effort undertaken during the five nights of sampling.	6
Table 3. The number of individuals of each species caught and the number of bat calls recorded on the detectors.	7
Table 4. Comparison of species of bats captured on proposed development areas versus conservation areas.	9
Table 5. Comparison of the number of bat detector calls recorded on proposed development areas versus conservation areas.....	10
Table 6. Summary of the detector and trapping results from proposed development areas versus conservation areas and corridors.	10

List of Figures

Fig. 1. Comparison of the number of bat calls recorded from the proposed development and conservation areas.....	11

List of Plates

Plate 1. The ultrasonic bat detector units used to record bat activity.....	5
Plate 2. The Common Sheathtail Bat <i>Taphozous georgianus</i> was found roosting in caves and rock crevices.	8
Plate 3. The Hoary Bat <i>Chalinolobus nigrogriseus</i> was the most common species in the area.	8
Plate 4. Yellow-bellied Sheathtail Bat <i>Saccolaimus flaviventris</i> was commonly recorded on the detectors and regularly seen in spotlights.....	12
Plate 5. Dusky Leaf-nosed Bat <i>Hipposideros ater</i> is a small cave-dwelling species.....	14
Plate 6. The Pygmy Long-eared Bat <i>Nyctophilus walkeri</i> is the smallest species of long-eared bat.	15
Plate 7. The Northern Cave Bat <i>Vespadelus caurinus</i> was found roosting in buildings at the Spirit Hills station.....	16
Plate 8. Northern Freetail Bat <i>Chaerophon jobensis</i> was not caught during this survey but could be identified by its distinctive echolocation call.	17

Introduction

This study was conducted to examine the impact of proposed clearing of land for agricultural development in Stage 2 of the Ord River Irrigation Area project. The proposal envisages the clearing of extensive areas of floodplain vegetation. Natural vegetation corridors will be retained along waterways and rocky hillsides for conservation purposes. This study surveyed the bat fauna of both the proposed development areas and the conservation corridors to predict the impact of the proposal on populations of bats.

Methods

Study area

The study was conducted on Legune and Spirit Hills Stations in the Northern Territory and on Ivanhoe and Carlton Hill Stations in Western Australia. These properties are adjacent along the Northern Territory and Western Australian border, north of Kununurra. The survey was conducted from the 6th to the 11th June 1999. The area consists of isolated rocky ranges of sandstone and quartzite of up to 200 m elevation, separated by floodplains of black cracking clays. The vegetation is predominantly open savannah woodland of mixed eucalypt species. Riverine (*Pandanus* and *Melaleuca*) forest and monsoon forest occur along waterways and near springs.

Survey sites were selected to sample the geographic range and the broad habitat types found in the area. Details of these sites are provided in Table 1.

Table 1. Location and habitat of sites used to survey bats.

Site	Location	Latitude	Longitude	Date	Habitat
1	Spirit Hills Camp	15° 26.3S	129° 01.2E	6/6/99	Rocky outcrop
2	Legune Rd (pit trap site 4)	15° 23.8S	129° 05.6E	7/6/99	Floodplain
3	Keep River, 0.4 km N Legune Rd	15° 23.9S	129° 04.5E	7/6/99	Riverine
4	Kneebone dam	15° 24.6S	129° 07.4E	7/6/99	Floodplain (dam)
5	1.3 km S of Kneebone Yd (pit trap site 3)	15° 25.4S	129° 07.5E	7/6/99	Floodplain
6	Nth Keep, 1.6 km N of Legune Rd	15° 22.7S	129° 07.7E	8/6/99	Floodplain (dam)
7	Nth Keep (pit trap site 5)	15° 21.3S	129° 07.1E	8/6/99	Floodplain (dam)
8	Keep River, end of tk past pit site 5	15° 20.1S	129° 05.7E	8/6/99	Riverine
9	Main Nth Keep Tk, 1 km N of tk to site 7	15° 21.3S	129° 07.8E	8/6/99	Floodplain (dam)
10	Nth Keep, fenceline W of locked gate	15° 19.2S	129° 07.9E	8/6/99	Floodplain
11	Nth Keep, 1.1 km S of locked gate	15° 19.6S	129° 07.8E	8/6/99	Floodplain
12	Milligans Tk, 3.6 km S of Legune Rd (pit trap site 2)	15° 28.0S	128° 58.5E	9/6/99	Floodplain
13	Milligans Lagoon	15° 37.0S	129° 00.3E	9/6/99	Riverine
14	Point Springs Tk, 5.2 km N of Legune Rd	15° 25.3S	128° 53.4E	10/6/99	Floodplain
15	Point Springs	15° 24.6S	128° 53.2E	10/6/99	Wetland/rocky hills
16	Cave Springs Cave	15° 31.7S	128° 50.0E	11/6/99	Rocky hills

Survey methods

Mist nets

Monofilament mist nets were set over water at dusk and monitored continuously for several hours. Net effort is expressed as net-hours (the number of mist nets times the hours of operation). Bats were caught in the net as they flew over the water to drink or to forage for insects. All bats captured were held in individual cloth bags until processed. Bats were weighed to the nearest 0.5 gram and a range of measurements taken to confirm species identification. Individuals were examined to determine sex, age and reproductive condition. All captured bats were released on the same night at their point of capture, after the nets had been closed.

Harp traps

Harp traps (Austbat, Lower Plenty Vic) were set in a variety of locations both near water and out in the open, often near large trees or along tracks where trees were denser. The traps consist of a large aluminium frame strung with fine fishing line with a catching bag underneath. They were set during the day and left for the entire night, as unlike mist nets they do not require constant attention. Traps were usually checked once or twice during the evening and again in the morning. Bats caught prior to the night checks were processed and released immediately. Those caught during the pre-dawn period were kept in individual cloth bags and released at the capture site the following evening after dark. Trapping effort is defined as the number of traps per night (trapnights).

Searching caves

Rocky outcrops and cliff lines were searched during the day for caves and rock splits which could provide potential roost sites for bats. All accessible caves and splits along a length of cliff line were examined for the presence of bats. Individuals were captured with a hand net, identified and released.

Trapping (using either mistnets, harp traps or hand caught in caves) allowed positive identification of individuals for all species, except for two species of broad-nosed bats *Scotorepens greyi* and *S. sanborni*. These species can not be reliably separated on external features (Churchill 1998), and hence in this report have been combined.

Ultrasonic detectors

Anabat ultrasonic detectors (Titley Electronics, Ballina NSW) were used to monitor levels of bat activity. These units detect the high frequency echolocation calls produced by insectivorous bats and divide the frequency down to an audible level. The calls are then downloaded onto a laptop computer via an Anabat zcain. The detector units, consisting of a detector, zcain, laptop computer and external 12 V batteries (Plate 1) were set at sites in the afternoon and collected in the morning. Sites were selected both near water and away from water. An additional unit, which was used primarily to record reference calls, was set for several hours during mistnetting.

Detectors have the advantage over trapping in that they do not require individuals to be handled for identification, and they are not dependent on flight paths to funnel bats into traps or nets. To confidently identify species using this technique it is necessary to obtain reference calls from the local bat population. This requires individuals being trapped and

their calls recorded on release. Detectors are appropriate for only certain types of bats. Several species cannot be recorded as their calls are too soft, of too high a frequency or because they do not use ultrasound (fruit bats). However many high-flying species of sheath-tail and freetail bats that are difficult to trap, are readily recorded using this technique.

Plate 1. The ultrasonic bat detector units used to record bat activity.



Reference calls were recorded from most trapped individuals on their release. To ensure that the released bat could be followed and distinguished from other bats flying in the area, individuals were fitted with a small chemical light (Cyalume). This capsule was lightly glued to the belly fur, and the bat released in the dark. To obtain diagnostic calls bats need to be free flying in the open. A total of 80 useable reference calls were obtained from 11 species. An example of a reference call from each species is provided in Appendix 1. We did not catch several species known from the region, and therefore were unable to obtain local reference calls from these species. Additional reference calls were obtained from elsewhere in Australia, however there is still a certain level of uncertainty about some call identifications, where known species maybe confused with other unrecorded species.

Identification of several species was not possible, even with good reference calls, as their calls overlap in all measurable parameters. *Chalinolobus nigrogriseus* and *Scotorepens greyii* were combined during the analysis as we, and other researchers (Linda Reinhold, pers. comm.) found their calls to be inseparable. From the limited number of *Scotorepens sanborni* calls available from north Queensland the calls of this species overlapped as well and so it was also combined with this group. Other species could be distinguished from some, but not all, calls. These were separated where possible and combined into a species complex where not possible. For example, *Chalinolobus gouldii* could at times be reliably identified, however other calls could not be confidently distinguished from *Scotorepens balstoni*.

A number of species trapped in the area are rarely recorded on detectors because of the limited range of their echolocation calls, for example the long-eared bats (*Nyctophilus*), leaf-nosed bats (*Hipposideros* and *Rhinonycteris*) and Ghost bats (*Macroderma*). We were able to obtain reference calls from these species only when they were very close to the detector microphone. For example, *Hipposideros ater* could only be detected about 20 cm from the microphone. Detecting this species on the remote detector units was therefore very unlikely.

Species of freetail bats (*Chaerophon* and *Mormopterus*) and sheath-tail bats (*Taphozous* and *Saccolaimus*) have loud and often distinctive calls. These are usually well represented in the call data. These species however are rarely captured, illustrating the importance of using a combination of techniques in a survey of bats.

Flying foxes (*Pteropus*) and blossom bats (*Macroglossus*) do not use echolocation and are therefore not detected using this method.

The amount of survey effort at each site using each of the techniques is shown in Table 2.

Table 2. The amount of survey effort undertaken during the five nights of sampling.

Site No.	Mist net hours	Trap nights	Detector hours	Cave Search
1		5	9.5	2 hr
2			12	
3		3	12	
4	6	2	1.5	
5		1	0 (failed)	
6		1		
7	9	1	12	
8		1		
9			12	
10		1	12	
11		1		
12		1	12	
13	12	5	14 *	
14		1	12	
15	12	4	12	1 hr
16				1 hr
Total	39 hr	27 trapnights	121 hr	4 hr

* two detectors were set at Milligans Lagoon – one for the entire night at the southern end of the lagoon, and one for 2 hrs while mistnetting at the northern end.

Limitations of the survey

Time limitations were a problem during this survey. With only 5 nights available it was difficult to sample the study area adequately. It also restricted the number of reference calls we could collect, which in turn influenced our ability to be able to identify the unknown detector calls. Species for which no reference calls were available (from either this or other areas) could not be identified during this study.

Results

A total of 14 species of bats were recorded during this survey of the Ord River Irrigation Stage 2 area. All these species are insectivorous, except for *Macroderma gigas* which is carnivorous. No fruit and blossom feeding species were recorded during this survey. During 39 hours of mistnetting and 29 harp trapnights, 98 individuals of 12 species were trapped (Table 3). An additional species, *Taphozous georgianus*, was caught during cave searches (Plate 2). A total of 5860 bat detector calls were identified revealing six species and two species complexes. The most commonly trapped species was *Chalinolobus nigrogriseus* with 47% of all captures. Similarly, the species complex of *Chalinolobus nigrogriseus/Scotorepens greyii/S. sanborni* was the most commonly recorded with over 60% of the calls attributed to this complex. The trapping results would suggest that the majority of these calls were *C. nigrogriseus*. The fast flying species which forage high above the canopy were recorded frequently using the detector, but were rarely trapped (eg. *Saccolaimus flaviventris*, *Taphozous georgianus*, *Chaerophon jobensis*). In contrast, the species with very low intensity echolocation calls were more readily trapped than recorded on the detectors (Table 3).

Table 3. The number of individuals of each species caught and the number of bat calls recorded on the detectors. Individuals hand caught include those from cave and building searches.

Species		Mist net	Bat trap	Hand caught	Bat detector
Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	1			654
Common Sheathtail Bat	<i>Taphozous georgianus</i>			10 *	261
Ghost Bat	<i>Macroderma gigas</i>	1			0
Dusky Leaf-nosed Bat	<i>Hipposideros ater</i>		4	1	0
Orange Leaf-nosed Bat	<i>Rhinonycteris aurantius</i>		1		0
Gould's Wattled Bat	<i>Chalinolobus gouldii</i>	2			27
Hoary Wattled Bat	<i>Chalinolobus nigrogriseus</i>	25	29		-
Large Bent-wing Bat	<i>Miniopterus schreibersii</i>	2	3		208
Arnhem Long-eared Bat	<i>Nyctophilus arnhemensis</i>		2		0
Pygmy Long-eared Bat	<i>Nyctophilus walkeri</i>		6		0
Inland Broad-nosed Bat	<i>Scotorepens balstoni</i>	2			0
Little/Northern Broad-nosed Bat	<i>Scotorepens greyii/sanborni</i>	1			-
Northern Cave Bat	<i>Vespedalus caurinus</i>	2	17	5	568
Northern Freetail Bat	<i>Chaerophon jobensis</i>				30
Composite groups	<i>Chalinolobus nigrogriseus</i> / <i>Scotorepens greyii</i> / <i>S. sanborni</i>				3566
	<i>Chalinolobus gouldii</i> / <i>Scotorepens balstoni</i>				49
Total		36	62	16	5860

* another 20 seen but not caught.

Plate 2. The Common Sheathtail Bat *Taphozous georgianus* was found roosting in caves and rock crevices.



To assess the impact of the proposed development on the foraging habitat of the bats in the region, a comparison was made between sites located in the floodplain habitat and those associated with riverine or rocky habitat which are proposed as conservation reserves. Results from trapping data is presented in Table 4. Six species were caught in the development area while 11 species were caught in the conservation areas. The most commonly trapped species, in both the development and conservation areas, was *Chalinolobus nigrogriseus* (Plate 3). Several of the species caught in the conservation areas but not in the floodplain area were species which roost in caves (eg. *Macroderma gigas*, *Hipposideros ater*, *Rhinonycteris aurantius*). One individual of the *Scotorepens greyii/sanborni* complex was caught in the development area, while none were trapped in the conservation area.

Plate 3. The Hoary Bat *Chalinolobus nigrogriseus* was the most common species in the area.



Table 4. Comparison of species of bats captured on proposed development areas versus conservation areas.

a) Proposed development areas – floodplain habitat.

Species	Site								Total
	4	5	6	7	10	11	12	14	
<i>Chalinolobus gouldii</i>				2					2
<i>Chalinolobus nigrogriseus</i>	2		9	19					30
<i>Miniopterus schreibersii</i>	2		1			1			4
<i>Scotorepens balstoni</i>				1					1
<i>Scotorepens greyii/sanborni</i>	1								1
<i>Vespertilio caurinus</i>			1						1
Number of species	3	0	3	3	0	1	0	0	6
Number of captures	5	0	11	22	0	1	0	0	39

b) Proposed conservation areas – riverine and rocky habitat.

Species	Site						Total
	1	3	8	13	15	16	
<i>Saccolaimus flaviventris</i>				1			1
<i>Taphozous georgianus</i>	1				3	6	10
<i>Macroderma gigas</i>				1			1
<i>Hipposideros ater</i>	3				1	1	5
<i>Rhinonycteris aurantius</i>	1						1
<i>Chalinolobus nigrogriseus</i>	3	15		6			24
<i>Miniopterus schreibersii</i>	1						1
<i>Nyctophilus arnhemensis</i>		1			1		2
<i>Nyctophilus walkeri</i>		1			5		6
<i>Scotorepens balstoni</i>					1		1
<i>Vespertilio caurinus</i>	8	8		3	4		23
Number of species	6	4	0	3	6	2	11
Number of captures	17	25	0	11	15	7	75

Six species and one species complex were identified using the detectors. All of these were found in both the proposed development and conservation areas (Table 5). However, overall levels of bat activity were much lower in the development areas, with seven times as many calls recorded in the conservation areas as in the development areas (86 calls/hr compared to 12 calls/hr). The comparative levels of activity in the two areas is shown in Fig. 1. The *Chalinolobus nigrogriseus*/*Scotorepens greyii*/*S. sanborni* complex was the most commonly recorded in both areas, representing 75% of calls in the floodplain and 59% in the conservation areas. *Taphozous georgianus* and *Vespertilio caurinus* were recorded proportionally more often in the conservation areas (5% vs 0.5% and 12% vs 0.3% of total records respectively). The other species were recorded in the same relative proportions in both areas.

Table 5. Comparison of the number of bat detector calls recorded on proposed development areas versus conservation areas.

a) Proposed conservation areas – riverine and rocky habitat.

Species	Site							Total	Calls / hr
	2	4	7	9	10	12	14		
<i>Saccolaimus flaviventris</i>	4	25	2	11	9	3	1	55	0.89
<i>Taphozous georgianus</i>				1	1		2	4	0.07
<i>Chalinolobus gouldii</i>		3				1		4	0.07
<i>Chalinolobus nigrogriseus</i> / <i>Scotorepens greyii/sanborni</i>	10	151	4	218	16	167	4	570	9.27
<i>Miniopterus schreibersii</i>		8		5	18	2		33	0.54
<i>Vespedalus caurinus</i>					1		1	2	0.03
<i>Chaerophon jobensis</i>	1		1					2	0.03
Unidentified	3	2		13	28	31	13	92	1.50
Number of 'species'	3	4	3	4	5	4	4	7	
Number of calls	18	191	7	248	73	204	21	762	12.39

b) Proposed conservation areas – riverine and rocky habitat.

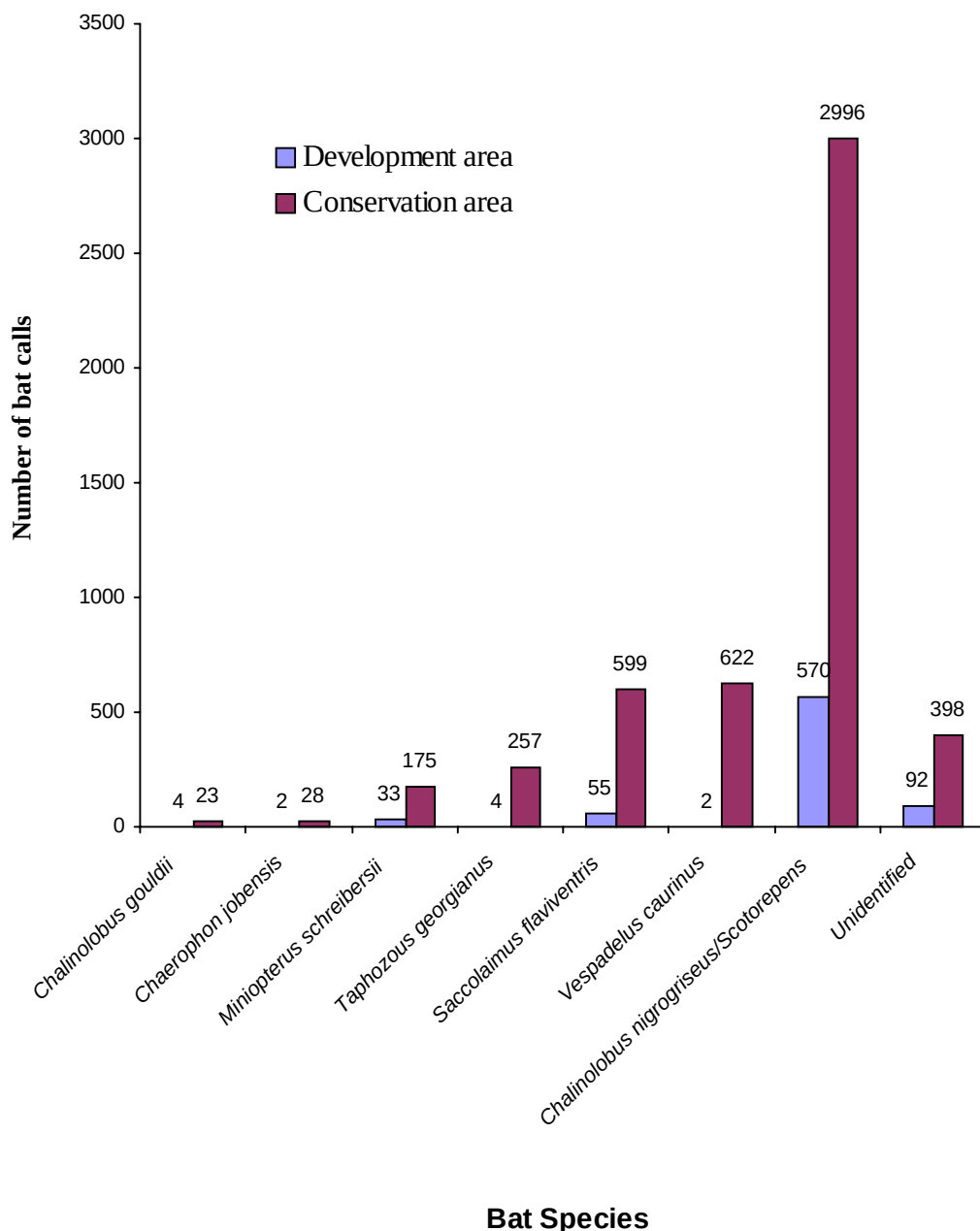
Species	Site				Total	Calls / hr	Total both areas	% total records
	1	3	13	15				
<i>Saccolaimus flaviventris</i>	84	246	223	46	559	9.39	654	11.1%
<i>Taphozous georgianus</i>	231	21	1	4	257	4.32	261	4.5%
<i>Chalinolobus gouldii</i>		1	16	6	23	0.39	27	0.5%
<i>Chalinolobus nigrogriseus</i> / <i>Scotorepens greyii/sanborni</i>	627	1225	302	842	2996	50.35	3566	60.9%
<i>Miniopterus schreibersii</i>	136	8	21	10	175	2.94	208	3.5%
<i>Vespedalus caurinus</i>	66	160	187	209	622	10.45	624	10.6%
<i>Chaerophon jobensis</i>	18	7	2	1	28	0.47	30	0.5%
Unidentified	92	174	58	74	398	6.69	490	8.4%
Number of 'species'	6	7	7	7	7		7	
Number of calls	1254	1842	810	1192	5098	85.68	5860	

Table 6. Summary of the detector and trapping results from proposed development areas versus conservation areas and corridors.

Proposed Development Areas floodplain habitat (Sites 2, 4, 5, 6, 7, 9, 10, 11, 12, 14)	Proposed Conservation Areas waterways & rocky outcrops (Sites 1, 3, 8, 13, 15, 16)
• average 12.4 bat calls / hr • 762 calls during 61.5 detector hr • 7 species recorded	• average 85.7 bat calls / hr • 5098 calls during 59.5 detector hr • 7 species recorded
• 6 species captured • 39 captures during 15 net hours and 8 trap nights	• 11 species captured • 72 captures during 24 net hours and 19 trap nights
• total of 9 species recorded	• total of 13 species recorded

An overall comparison of the results from the sites in the conservation and proposed development areas is provided in Table 6. Species diversity and abundance were higher in the conservation areas. All the species recorded in the development area were recorded in the conservation area, with the possible exception of *Scotorepens greyii/sanborni*. This species complex was only caught in the development area. As its calls could not be distinguished from the common *Chalinolobus nigrogriseus* its distribution and habitat use can not be fully ascertained. These species however are generally common and widespread in northern Australia.

Fig. 1. Comparison of the number of bat calls recorded from the proposed development and conservation areas.



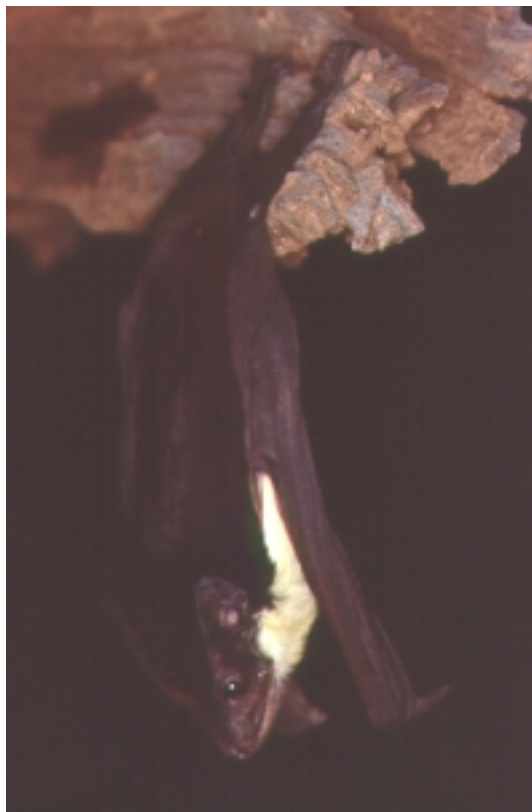
Annotated species list

Species recorded during the study

Yellow-bellied Sheathtail Bat *Saccolaimus flaviventris*

Saccolaimus flaviventris is a fast, high-flying species that forages over a wide region searching for insect prey (Plate 4). They usually roost in tree hollows but have been recorded from a variety of strange sites, such as cracks in dry clay. They are rarely captured, as they stay high above the canopy out of range of nets and traps. During the survey they were often seen in the beam of a spotlight more than 10 m above the ground. This species can be identified in flight by its large size, flight pattern and distinctive white belly fur. The one individual we caught was coming down to water to drink at Milligans Lagoon. Although rarely caught, they have loud and distinctive calls and are readily recorded using detectors. They occur in all habitats and were encountered at all detector sites.

Plate 4. Yellow-bellied Sheathtail Bat *Saccolaimus flaviventris* was commonly recorded on the detectors and regularly seen in spotlights.



Common Sheathtail Bat *Taphozous georgianus*

This species is an inhabitant of the rocky hills and outcrops throughout the study area. They usually roost in caves and rock splits in small groups of 2 to 3, and several were found while searching cliff lines at Spirit Hills and Point Springs. A larger colony of 35 individuals was found roosting at Cave Springs. They typically roost in the twilight zone

near the entrance to caves and crevices, however retreat into darker sections when disturbed. They are fast high-flying bats that are capable of foraging for insects over large areas. All roosting sites for this species in this area will be within the proposed conservation areas. The detector results revealed that the majority of the foraging also occurs close to rocks, with 98% of the calls of this species recorded from the proposed conservation areas.

Ghost Bat *Macroderma gigas*

This species is an inhabitant of caves and rock splits. It is still moderately common in the Top End of the Northern Territory although it has suffered a massive decline in its range in inland and southern Australia this century (Churchill and Helman 1990). This unusual species is carnivorous and eats birds, lizards, small mammals, bats and large invertebrates. It was recorded only once during the survey, with a single individual captured in a mist net at Milligans Lagoon. Due to its quiet echolocation call it was not expected to be recorded on the detectors. It is able to utilise a broad range of habitats. Most foraging occurs within 2 km of roost sites.

Orange Leaf-nosed Bat *Rhinonycteris aurantius*

Rhinonycteris aurantius is a rare species that is restricted in its range to the Top End, Kimberley and Pilbara. It only roosts in caves with unusually high temperature and humidity (28°C to 32°C, and 96-100% humidity) (Churchill 1998). These cave conditions are rare and this usually limits the distribution of the species. The presence of this species in the area is of conservation significance. Only one individual was captured, in a harp trap near the Spirit Hills Camp. It is not known where this individual was roosting. No caves located in the area matched the microclimate used by this species, except for Cave Springs. One specimen was collected from this cave in 1966, however, none were using the site during our survey, nor during numerous visits over the last 20 years (Churchill pers. obs.). As the caves often used by this species have small entrances it is possible that there are undiscovered caves in the Cave, Pincombe or Weber Ranges that may be suitable for this species. Individuals can forage up to 30 km from their roost site. Cave Springs is 25 km from where this individual was caught at Spirit Hills.

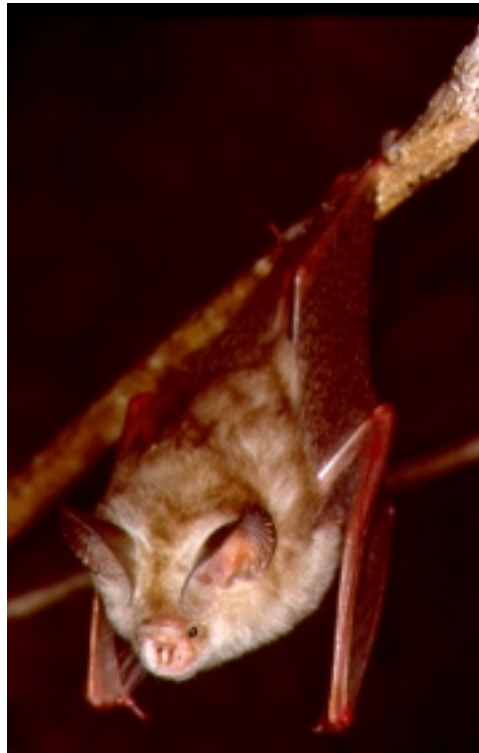
Dusky Leaf-nosed Bat *Hipposideros ater*

Hipposideros ater is also a restricted cave dwelling species (Plate 5). This slow flying species does not range far from its cave roosts and usually forages in cluttered habitats. Several were captured in bat traps near rocky areas, two were seen in the cave at Cave Springs and a dead one was found in a small cave near Spirit Hills Camp.

Gould's Wattled Bat *Chalinolobus gouldii*

Chalinolobus gouldii is a very common species that is widespread throughout Australia. It is a tree-dwelling species that flies rapidly, usually below the canopy. It was surprisingly uncommon in the study area with only two individuals captured. It was represented in the detector calls in only low numbers and at only a few of the sites, mostly in the conservation areas.

Plate 5. Dusky Leaf-nosed Bat *Hipposideros ater* is a small cave-dwelling species.



Hoary Wattled Bat *Chalinolobus nigrogriseus*

Chalinolobus nigrogriseus is a very common species across northern Australia. Like *C. gouldii* it roosts in tree hollows and eats flying insects. It was the most common species recorded in this study. 60% of all the echolocation calls were identified as the species complex which included this species. It was the most commonly captured bat (54 captures) representing 47% of all bats trapped. This suggests that the majority of the calls recorded as the species complex were likely to be *C. nigrogriseus*. It appears to be the dominant species of both the floodplain and proposed conservation areas, and the call was detected at every site. It was encountered far more commonly in the conservation areas than the proposed development area, with the recording rate over five times greater.

Large Bent-wing Bat *Miniopterus schreibersii*

Miniopterus schreibersii is a common cave-dwelling species of northern and eastern Australia. In northern Australia it roosts in a variety of cave climates and is often found in small colonies. It is not known where this species roosts within the study area. It is a very mobile species and will forage over a large area. It was captured more commonly in the proposed development area (although this is based on only a small number of captures), but their calls were detected more commonly in the conservation areas.

Arnhem Long-eared Bat *Nyctophilus arnhemensis*

Nyctophilus arnhemensis is restricted to the Top End and the Kimberley. It is rarely found far from the coast or from waterways. It has a preference for riverine, monsoon and mangrove vegetation and will roost under the loose bark of *Melaleuca* trees and in *Pandanus*. This species was only captured twice, both times near water along the Keep

River and at Point Springs. The echolocation call is faint, and like most species of long-eared bats, is rarely recorded on detectors.

Pygmy Long-eared Bat *Nyctophilus walkeri*

Nyctophilus walkeri is restricted to the Top End and western Kimberley (Plate 6). The capture of 6 individuals during this study represents a slight range extension, the first record from the eastern Kimberley. This is not unexpected as there has been little previous survey of bats in this region and it is likely that their range will be found to be continuous along the coast. They have a preference for foraging in the dense vegetation along riverbanks and mangroves and are rarely captured far from water. During this study individuals were caught along the Keep River and at Point Springs.

Plate 6. The Pygmy Long-eared Bat *Nyctophilus walkeri* is the smallest species of long-eared bat.



Inland Broad-nosed Bat *Scotorepens balstoni*

Scotorepens balstoni is a common species throughout inland Australia. Its distribution rarely extends to the coast and its presence in the study area was a surprise and a range extension of several hundred kilometres. Only two individuals were captured, one at Point Springs, and one in the proposed development area in the northern Keep. Their echolocation calls overlap with *Chalinolobus gouldii* and none of the calls recorded during this study could be confidently attributed to this species. Therefore little data could be obtained on their use of habitats within the area.

**Little Broad-nosed Bat and Northern Broad-nosed Bat *Scotorepens greyii*/
*Scotorepens sanborni***

It is not possible to distinguish these two species from external characteristics, and therefore it was necessary to combine them. Broad-nosed bats are common and usually readily caught throughout northern Australia. It was therefore surprising that only one was caught during this survey. This individual was trapped in the proposed development area at the Kneebone dam. Their echolocation calls are indistinguishable from those of the

common *C. nigrogriseus* and these were combined into a species complex (*C. nigrogriseus* / *S. greyii* / *S. sanborni*) during the call analysis. Without further survey effort it is difficult to say how common these species are likely to be in the area.

Northern Cave Bat *Vespadelus caurinus*

Vespadelus caurinus is restricted to the Top End and the Kimberley where it is found commonly, roosting in small numbers in caves, abandoned mines and buildings (Plate 7). A colony of 6 was found roosting in one of the rooms in the Spirit Hills camp, and judging by the quantity of droppings on the floor in these rooms, this building is a common roost site. Only one individual was captured in the development area, but they were captured at most sites in the conservation areas. They were recorded commonly at all conservation sites using the detectors, but by only a single call at two sites in the proposed development area. The roost sites of this species are likely to be in the conservation areas, and from the detector data it is apparent that this species rarely forages away from these areas, and little use is made of the floodplain.

Plate 7. The Northern Cave Bat *Vespadelus caurinus* was found roosting in buildings at the Spirit Hills station.



Northern Freetail Bat *Chaerophon jobensis*

This species (Plate 8) was not captured during the study but it has a distinctive echolocation call that was recorded at all sites in the conservation area. In contrast, it was only recorded at two sites in the proposed development areas, by a single call at each. It therefore appears to make little use of the floodplain in this area. It is widespread across northern Australia and extends well into the arid regions. It is a fast, high-flying species that usually forages well above the canopy for large insects. It usually roosts in tree hollows, but will occasionally use caves or buildings.

Plate 8. Northern Freetail Bat *Chaerophon jobensis* was not caught during this survey but could be identified by its distinctive echolocation call.



Species not recorded during the study but expected to be present

Northern Long-eared Bat *Nyctophilus bifax*

This species occurs in a discontinuous belt along the east and north coasts of Australia. It favours wetter habitats such as monsoon forests and riverine vegetation but also extends a short distance out onto the floodplain. It is not a commonly captured species but is likely to occur in the study area in the conservation areas, along the rivers and waterways.

Lesser Long-eared Bat *Nyctophilus geoffroyi*

Nyctophilus geoffroyi is one of the most common and widespread bats in Australia. It is found in almost all habitats and roosts almost anywhere (except caves). It was surprising therefore, that none were caught during this study. As with all long-eared bats its echolocation calls are faint and difficult to record. While we did not find this species in the area, it is likely to occur there or nearby.

Beccari's Freetail Bat *Mormopterus beccarii*

Mormopterus beccarii is a common species across tropical Australia and uses a wide range of habitats from rainforests to arid shrublands and spinifex. It usually roosts in tree hollows. It was not captured during this study and was not recorded on the bat detectors. We were unable to obtain definite reference calls on which to base call identification, however, it appears that its calls are similar to those of *Taphozous georgianus*. Therefore it is possible that calls may have gone unrecognised. Elsewhere in its range *M. beccarii* is often recorded at waterholes in floodplain areas, and as virtually all of the calls identified as *T. georgianus* in this study were close to rocky areas used as roosts by *T. georgianus* it is most likely that they did represent that species. To determine if the species does occur in the region further trapping would be required. When individuals were caught reference

calls could be collected which would then enable the use of detectors to fully ascertain its distribution and habitat use.

Black Flying-fox *Pteropus alecto*

This flying-fox was not seen during the survey. These bats are frugivorous and nectarivorous, feeding primarily on the blossoms of eucalypts, Melaleuca and Grevillea. Their local distribution is very dependent on what trees are in fruit or flower at the time. Very few trees were in flower in the study area during our survey, and hence it was not surprising that we did not record them. The aboriginal people that we met at the camp told us that they form large camps near Milligans Lagoon when these trees are in flower. They are common across northern Australia and can occur in camps containing many thousands of individuals. Although the development will result in the loss of flowering trees used for foraging, the retention of the vegetation along the waterways is the most important consideration for their conservation. These areas provide the most suitable camp sites and also support many flowering trees such as the Melaleucas.

Little Red Flying-fox *Pteropus scapulatus*

This species was not recorded during the study but it would undoubtedly occur there at times. Like *P. alecto* they depend on flowering trees for their food. They tend to be more solitary and nomadic than *P. alecto*. The proposed development, while reducing the availability of food resources, would cause relatively little impact on this species.

Other species of bats that may occur in the study area

Northern Blossom Bat *Macroglossus minimus*

Macroglossus minimus has not been recorded from this part of the Kimberley but it is possible that it does occur there. It is restricted to riverine vegetation and monsoon thickets. If it does occur in the study area, it is likely to be found only in the conservation areas, and hence the impact of the proposed development on this nectar-eating species would be minimal.

Northern Pipistrelle *Pipistrellus westralis*

Pipistrellus westralis is a coastal species that has been recorded from mangroves and along waterways into Melaleuca swamps and freshwater mangroves. It is possible that it occurs along the lower reaches of the Keep River, but is unlikely to occur elsewhere in the study area. No individuals were caught during the survey, and it was not possible to obtain reference calls of this species. To ascertain its presence in the area, further trapping would be required and reference calls collected. If it does occur in the area its preferred habitat is unlikely to be affected by development.

Discussion

Effect of clearing on bat populations

Clearing the floodplain vegetation will have an impact on the bat populations in that available foraging habitat will be reduced and some roost trees destroyed. However, the areas of natural vegetation preserved on the hills and along waterways will minimise the impact. During this survey all of the 14 species recorded were found in the proposed conservation areas except for *Scotorepens greyii/sanborni* which was only caught in the development area. As its calls could not be distinguished from the common *Chalinolobus nigrogrieus* it was not possible to ascertain its habitat use by the detector calls. These species are usually widespread and common and so it is likely that they also occur in the conservation areas. Bats are very mobile and consequently forage over a wide area, and in a number of habitats. Their most limited resources are roost sites. The retention of vegetation corridors along waterways will provide sufficient large trees and thick vegetation to support many roost sites for forest dwelling bats. The hills already provide suitable roost sites for the cave dwelling species. The data collected during this survey has shown that there is both a lower diversity and abundance of bats foraging out on the floodplain. In addition the species recorded on the floodplain are all ubiquitous species that occur commonly throughout much of northern Australia. While none of the species recorded during this survey are listed as threatened in the national Action Plan for Australian Bats (Duncan et al. in press), several are considered to be of conservation significance, such as *Macroderma gigas*, *Rhinonycteris aurantius* and *Hipposideros ater*. These are all cave dwelling and although parts of their foraging habitat will be modified (and probably support less invertebrate prey) their roosts will be left intact. This is also the case with the uncommon *Nyctophilus walkeri* and *N. arnhemensis*. These species are primarily restricted to riverine habitats and are known to roost under the bark of paperbark trees, in palm fronds, and inside Pandanus leaf clumps. All these roosts are found along rivers. The fast flying bats such as *Saccolaimus flaviventris*, *Taphozous georgianus* and *Chaerophon jobensis*, are likely to continue foraging above the floodplain even after clearing as they are commonly encountered in agricultural lands elsewhere in Australia. However, it is not known to what extent the abundance of their insect prey will be affected.

Suggestions for monitoring and further work

This survey was restricted by the limited time available. A longer survey would allow a more intensive coverage of the area. However, the overall pattern of greater diversity and abundance of bats in the proposed conservation areas compared to the development area is unlikely to change with further work. More trapping, however, may result in additional species being recorded for the area, such as *Nyctophilus geoffroyi*, *N. bifax*, *Pipistrellus westralis* and *Mormopterus beccarii*. Collection of reference calls from the latter two species would enable clarification of presence and distribution within the area using the detectors.

It would be useful to compare the diversity and abundance of bats using the existing sugar crops in the region to determine what species are able to forage over these modified areas.

An investigation of the abundance of invertebrate prey in these areas compared to the existing floodplain, riverine and rocky habitats would enable an assessment of the likely changes to the available food resources for the insectivorous species.

To determine more precisely where individuals roost and forage, a radio tracking study would be required. For cave-dwelling species such a study would ascertain how far from the roost sites individuals foraged and how important the floodplain area was as foraging habitat. For tree-dwelling species it could be determined what proportion of roosts were within the floodplain area compared to the conservation areas, and how much of the foraging time was spent in the floodplain. Radio tracking studies such as these can provide invaluable information on roost sites and foraging areas, however they require considerable time and financial investment.

A long-term monitoring program could be established to investigate the impact of clearing the floodplain vegetation. However, if this was to be undertaken, further pre-clearing sampling would be required. Bat trapping and detector results can be highly variable between nights and seasons and there needs to be a sufficiently large number of sites in both the conservation and development areas to enable this variation to be evened out. If for example, another one week sample was undertaken after the clearing had occurred, a comparison with the current study could be inconclusive. However, good baseline data on which to make future comparisons could be established with only several more weeks of sampling.

Acknowledgments

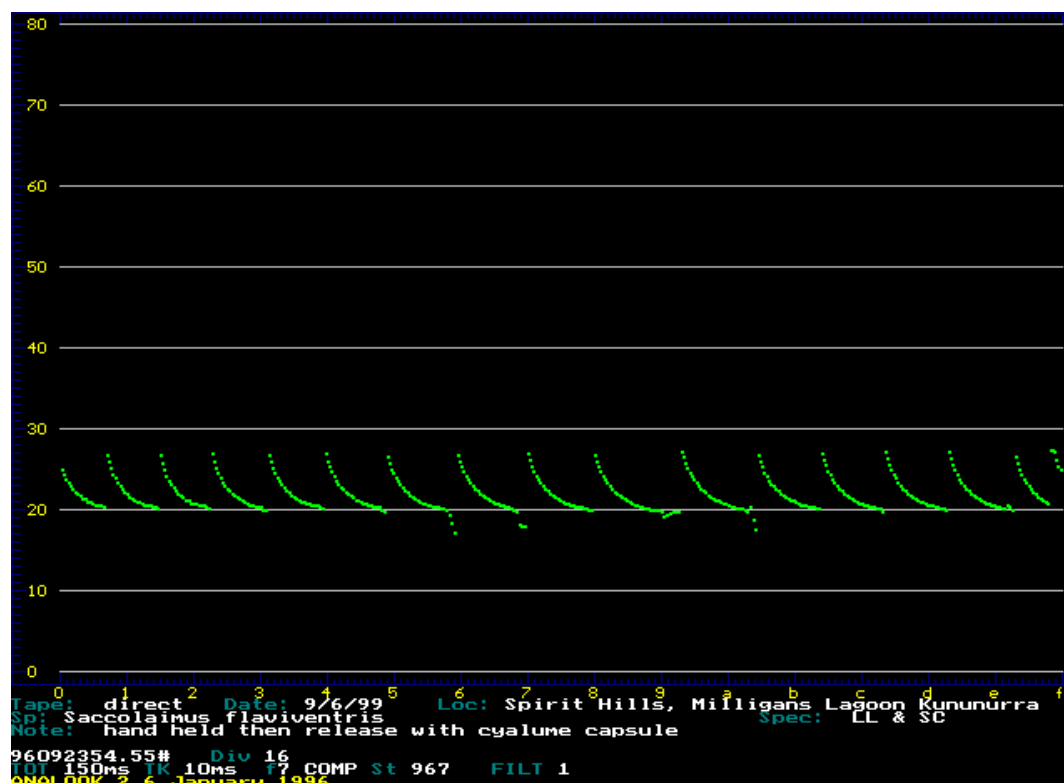
We would like to thank Bob Anderson and Eleanor Bennett of Kinhill for organising this survey, and Warren Ford, Phil and Rochelle Pyle for logistical support. Roger Coles, Greg Ford, Alex Kutt, Damian Milne, Linda Reinhold and Greg Richards kindly provided useful discussions on reference calls.

References

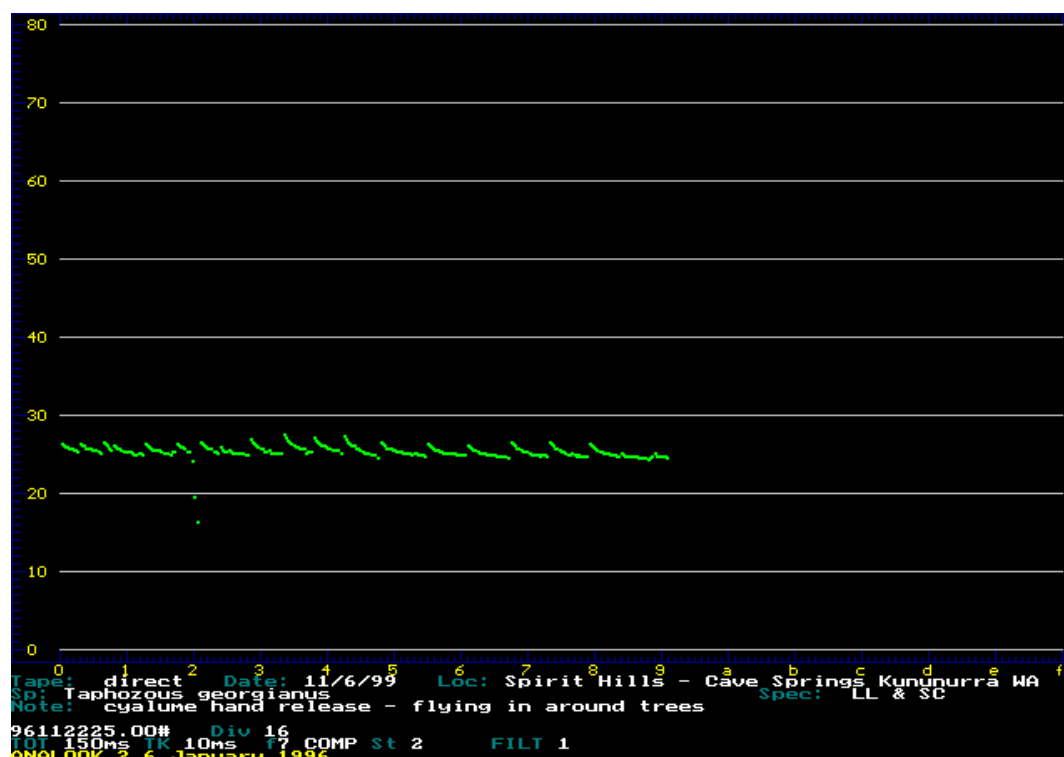
- Churchill, S. (1998). *Australian Bats*. Reed New Holland Publishers: Sydney. 230 pp.
- Churchill, S. K. and Helman, P.M. (1990). Distribution, population and status of the Ghost Bat, *Macroderma gigas* (Chiroptera: Megadermatidae) in central and South Australia. *Australian Mammalogy* **13**: 149-156.
- Duncan, A., Baker, G.B. and Montgomery, N. (in press). The 1999 Action Plan for Australian Bats. Environment Australia.

Appendix 1. Reference calls taken from individuals caught during the survey of the Ord Stage 2 survey.

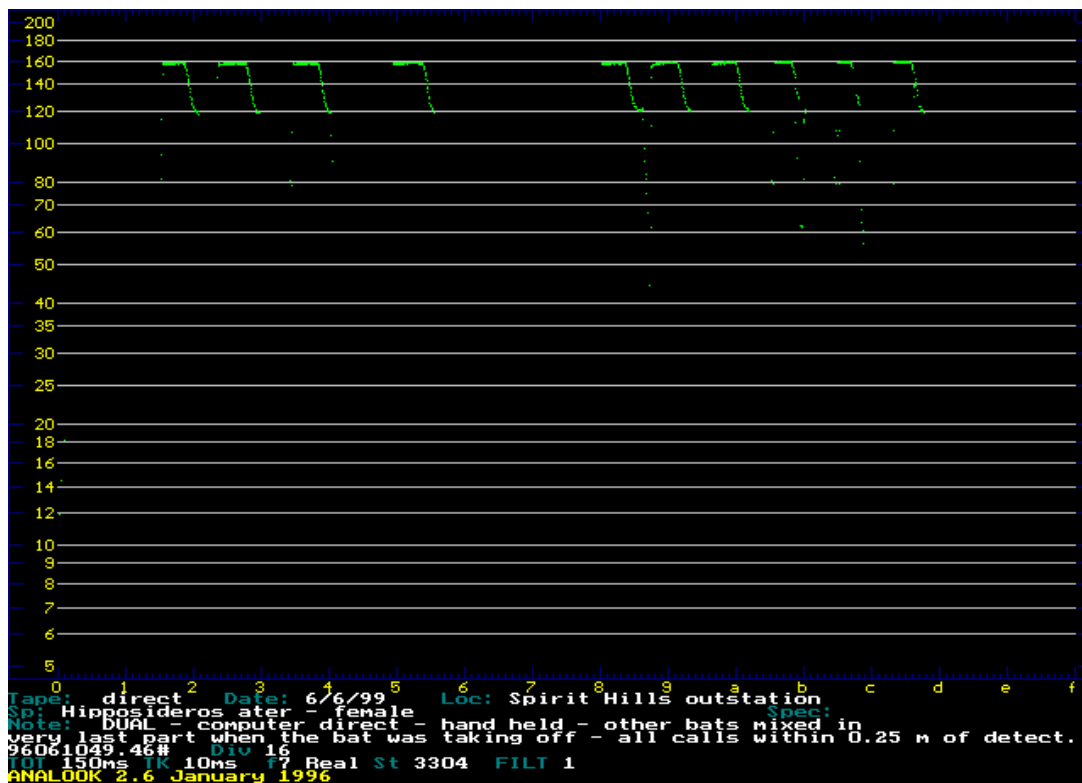
a) Yellow-bellied Sheathtail Bat *Saccolaimus flaviventris*.



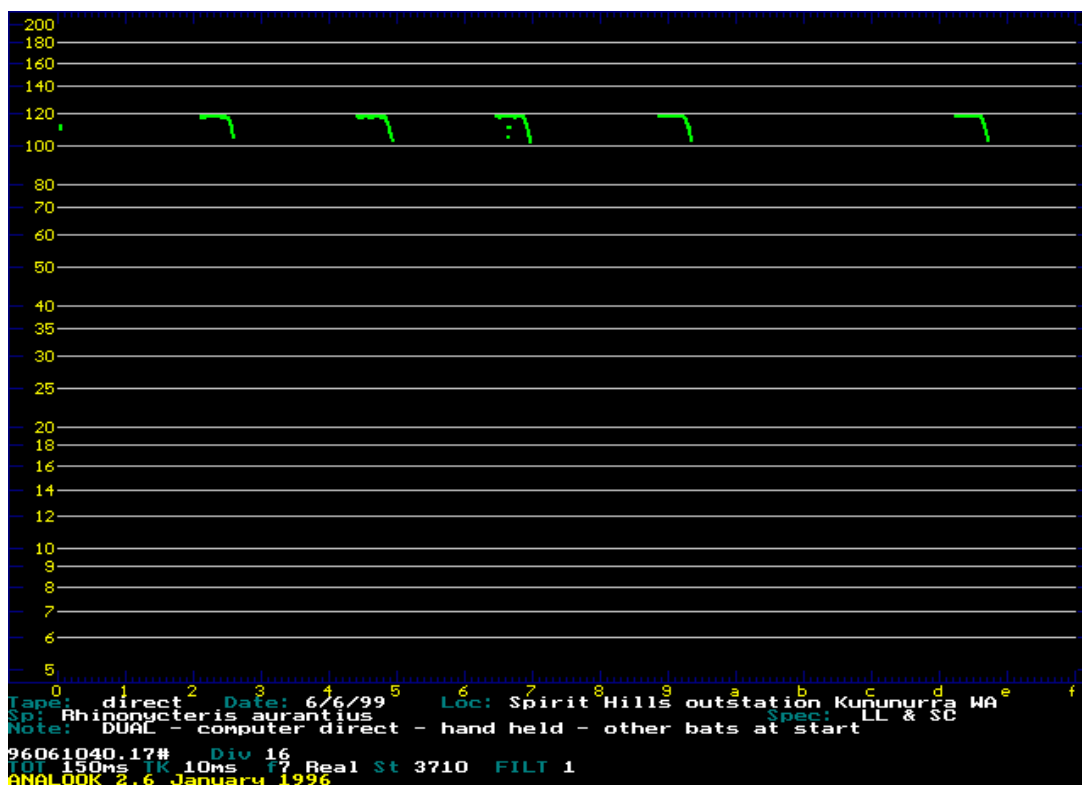
b) Common Sheathtail Bat *Taphozous georgianus*.



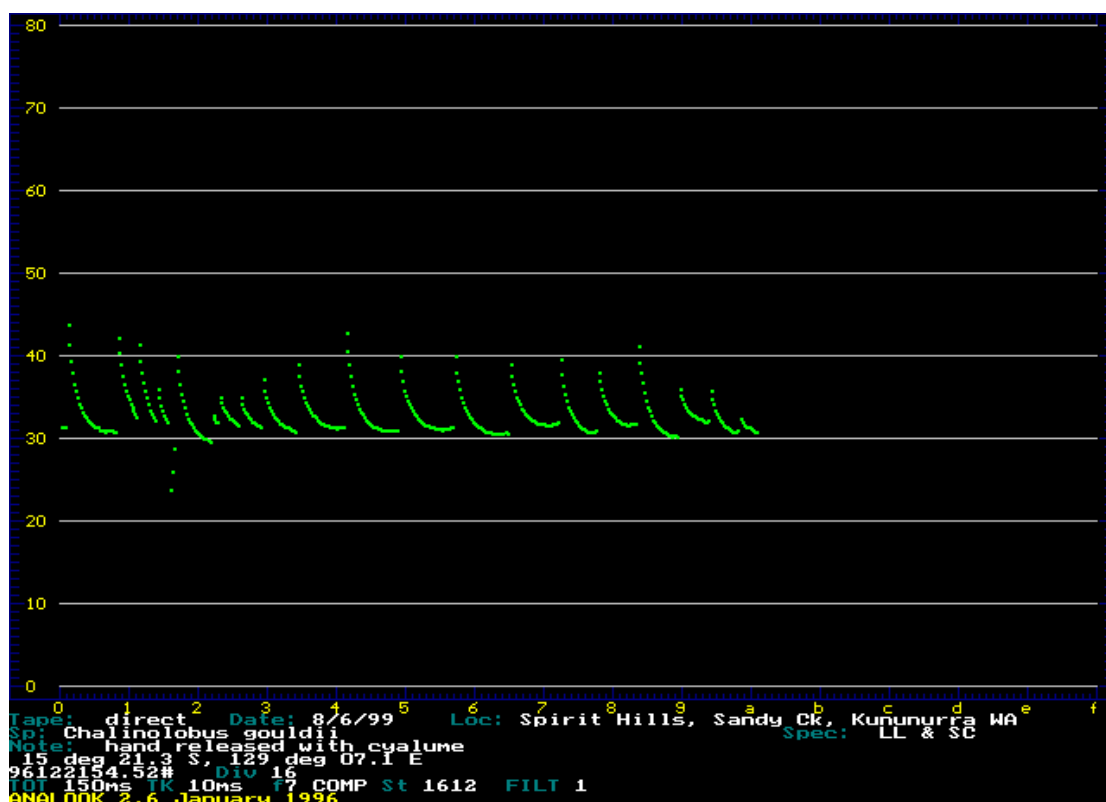
c) Dusky Leaf-nosed Bat *Hipposideros ater*.



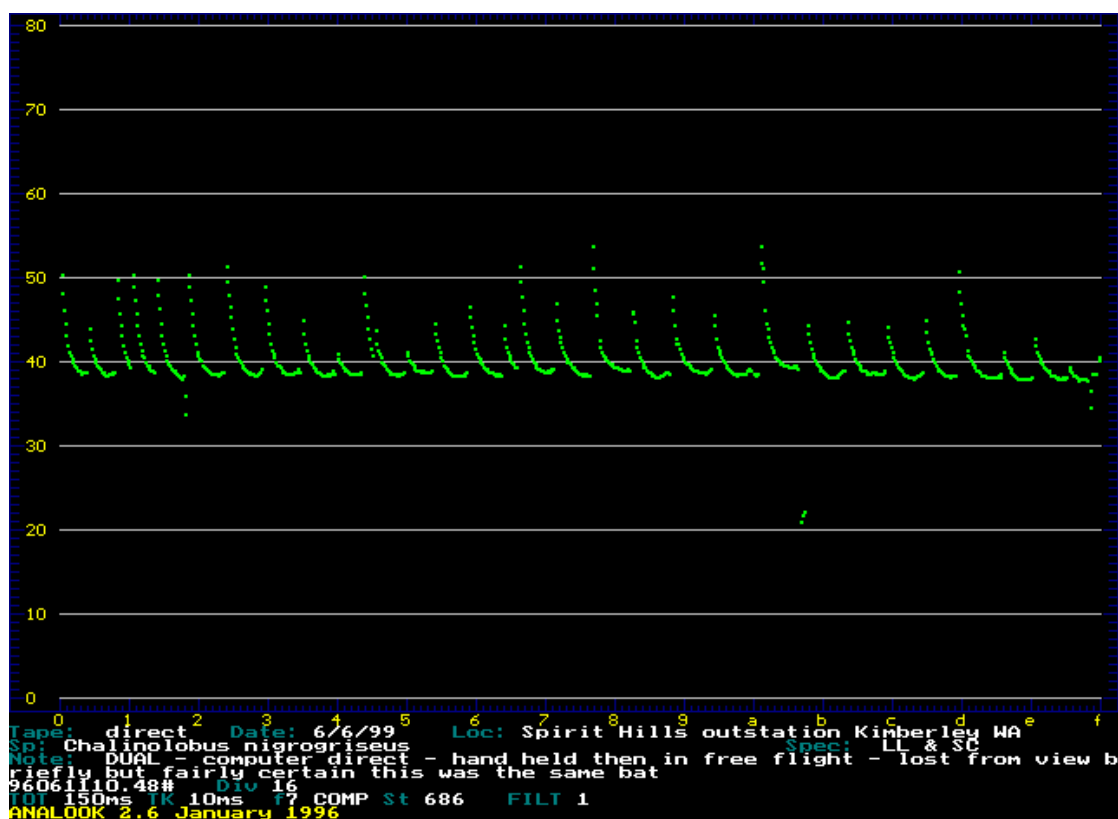
d) Orange Leaf-nosed Bat *Rhinonycteris aurantius*.



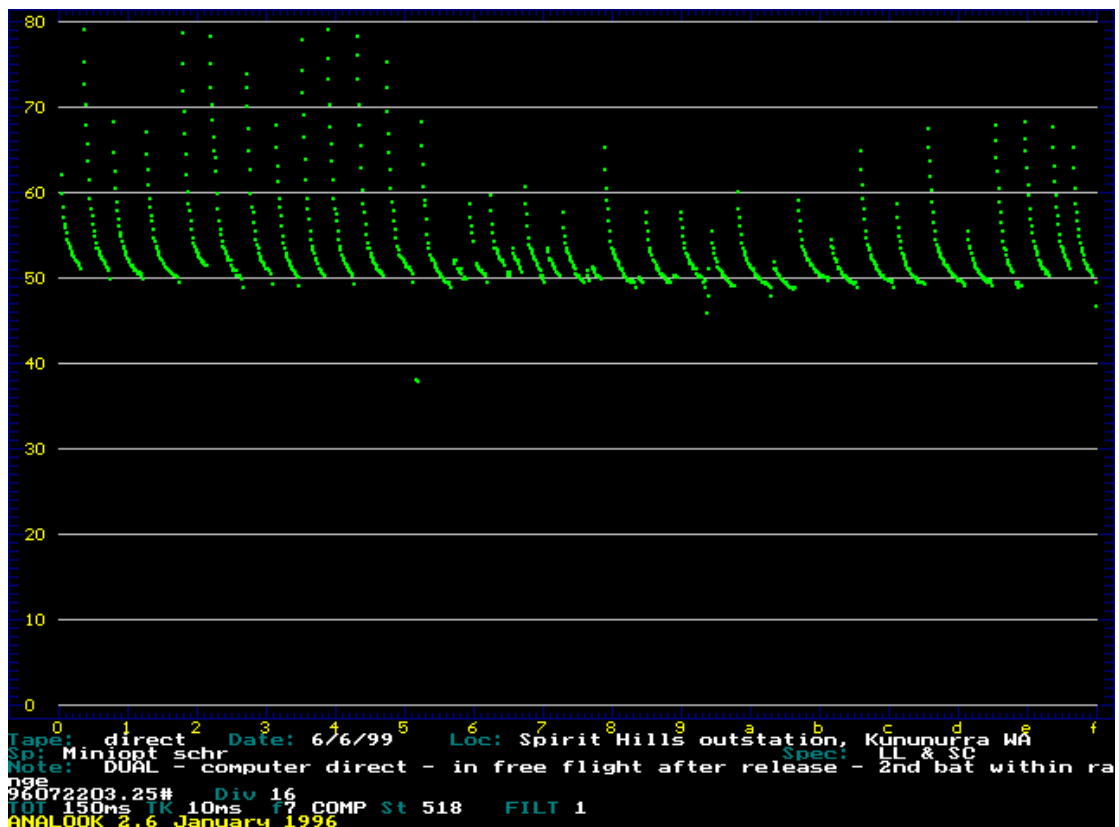
e) Gould's Wattled Bat *Chalinolobus gouldii*.



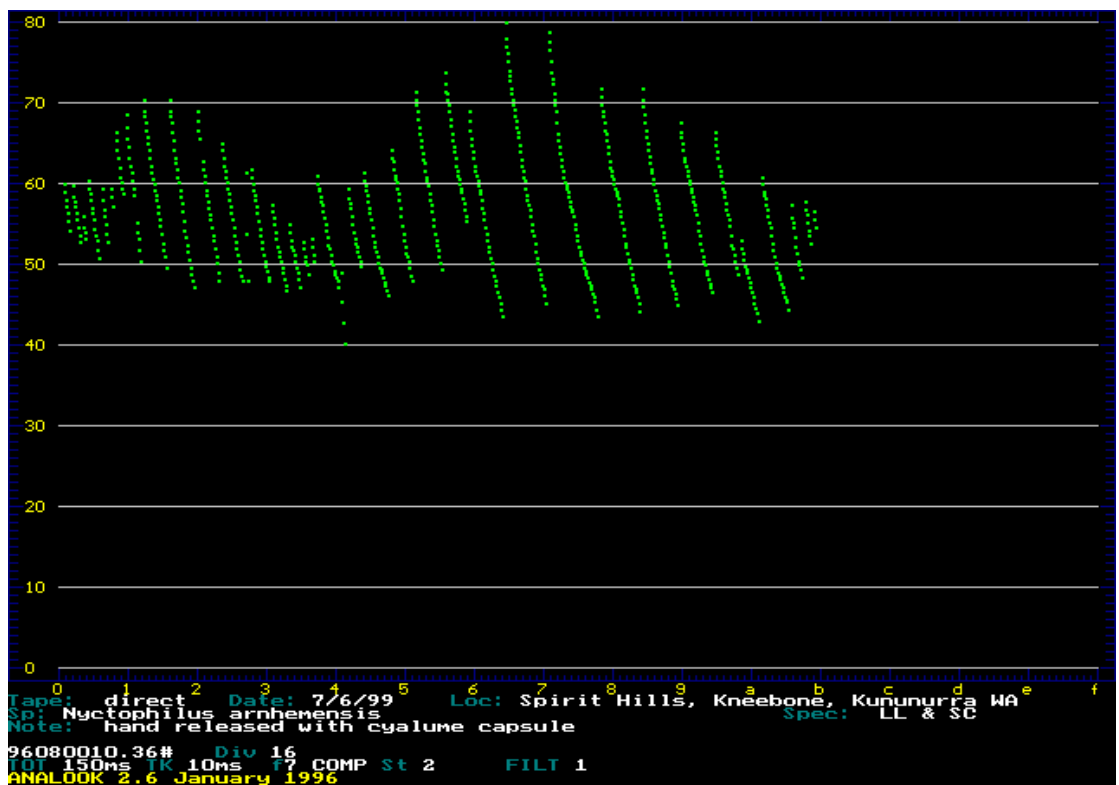
f) Hoary Wattled Bat *Chalinolobus nigrogriseus*.



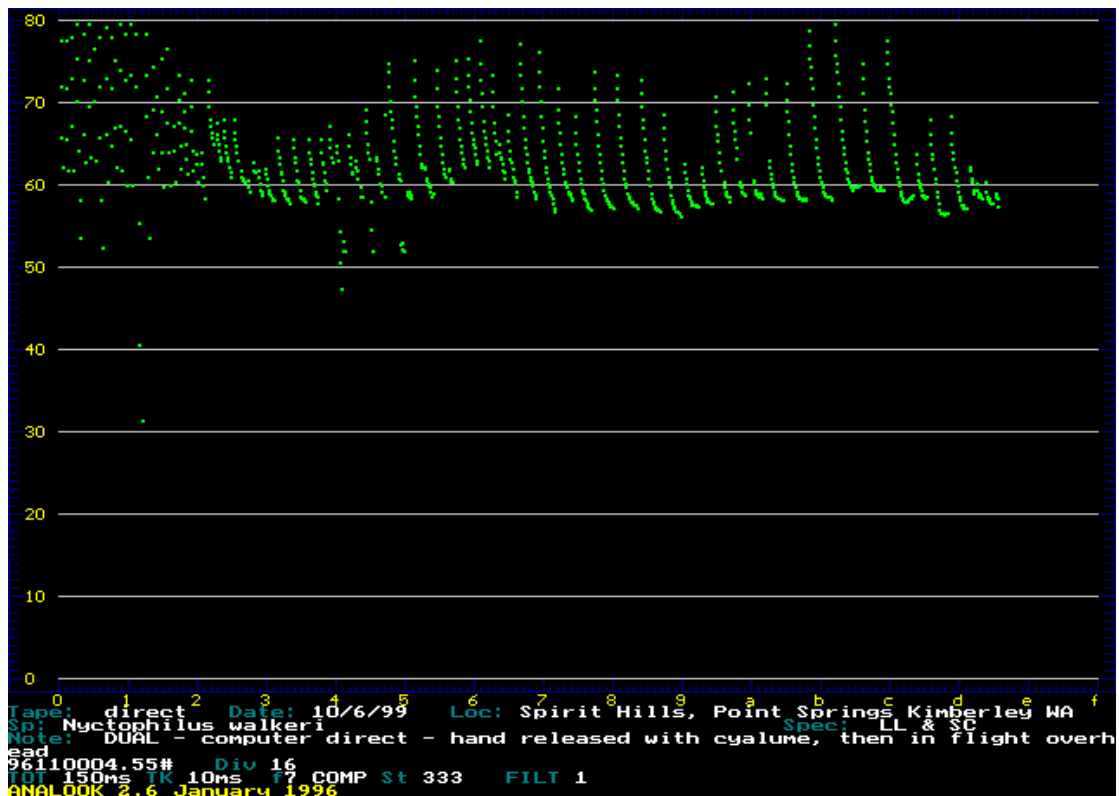
g) Large Bent-wing Bat *Miniopterus schreibersii*.



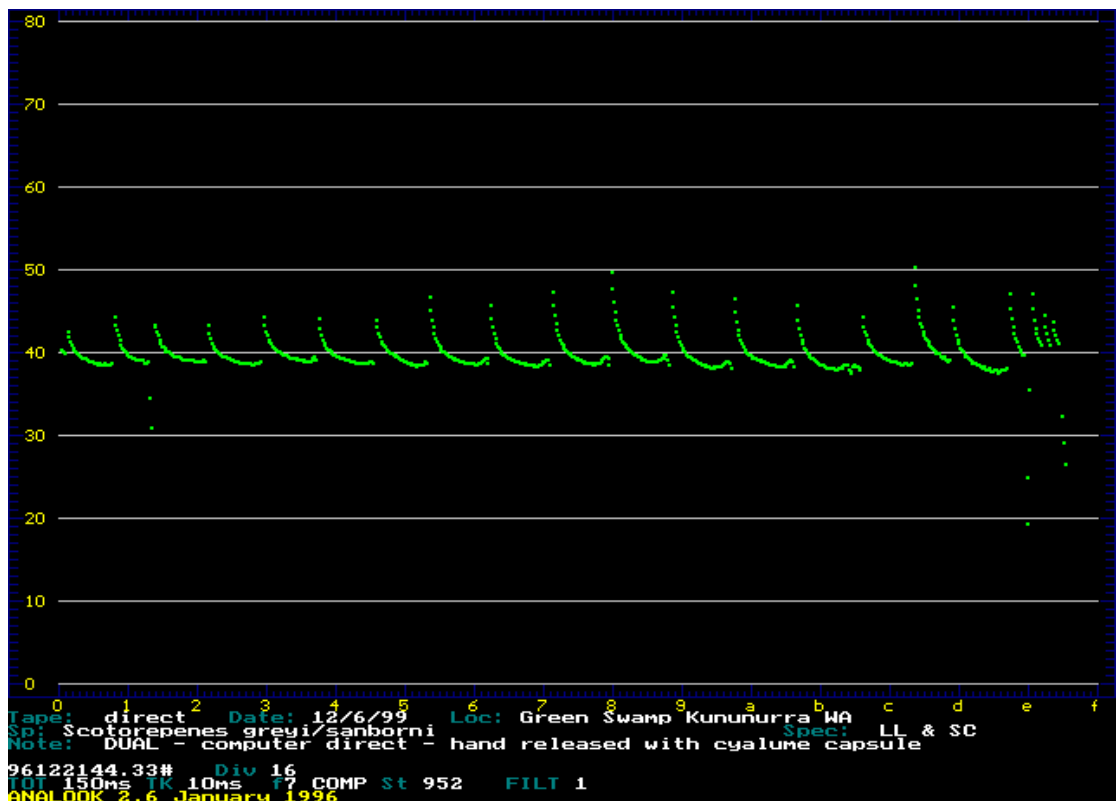
h) Arnhem Long-eared Bat *Nyctophilus arnhemensis*.



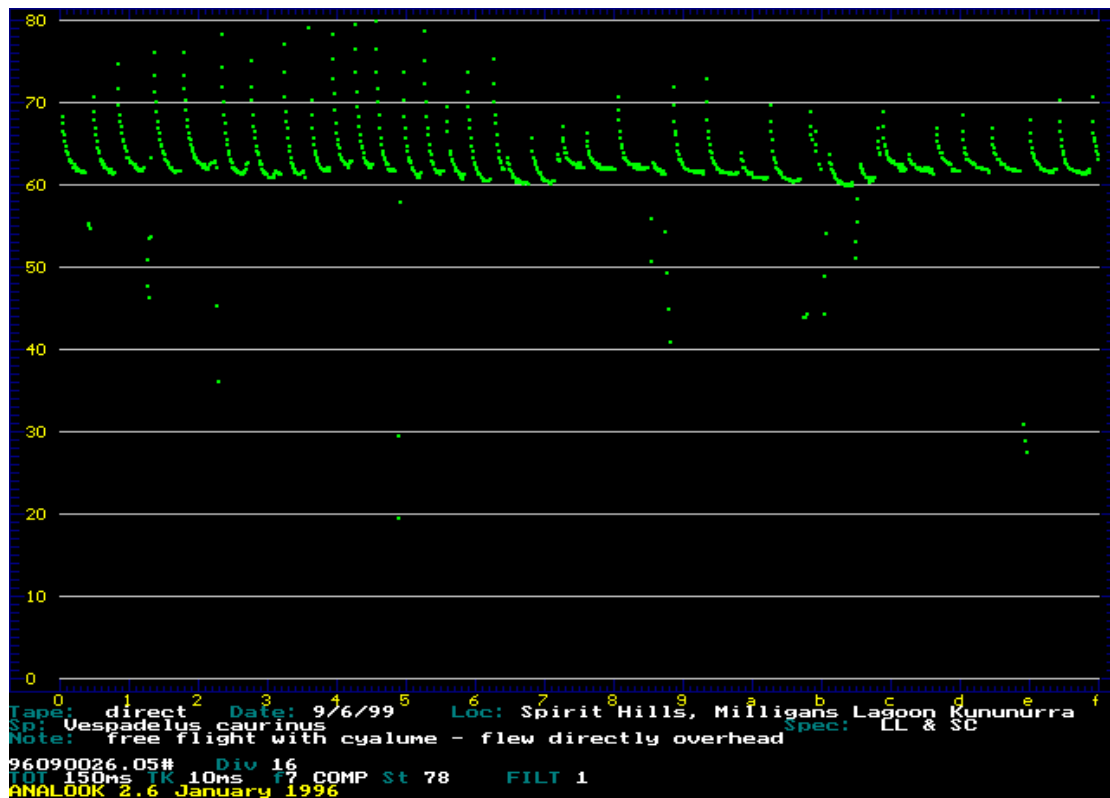
i) Pygmy Long-eared Bat *Nyctophilus walkeri*.



j) Little/Northern Broad-nosed Bat *Scotorepens greyii/sanborni*.



k) Northern Cave Bat *Vespadelus caurinus*.



APPENDIX K

TERRESTRIAL BIOLOGICAL ASSESSMENT

**WESFARMERS LIMITED
MARUBENI CORPORATION
WATER CORPORATION OF
WESTERN AUSTRALIA**

**ORD RIVER STAGE 11
M2 DEVELOPMENT AREA**

**TERRESTRIAL BIOLOGICAL
ASSESSMENT**

**ADDENDUM A:
REGIONAL BIODIVERSITY
AND REPRESENTATION**

JUNE 1999

Prepared by

ecologica

ENVIRONMENTAL CONSULTANTS

1.0 INTRODUCTION

Interest in the further development of the Ord River Irrigation Area has recently been renewed since Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia announced that they will undertake a study into the feasibility of establishing a raw sugar industry based on the development of the Weaber, Keep River and Knox Creek Plains (M2 Development Area). Biological diversity issues, particularly the maintenance of species and ecosystem diversity, are highly relevant in the context of the proposed development. The National Strategy for the Conservation of Australia's Biological Diversity maintains that ecologically sustainable management of all Australia's terrestrial and marine environments is essential for the conservation of biological diversity. The primary issues examined in this document, therefore, relate to the protection of biological communities and hence protection of biological diversity.

Representation of areas supporting unique vegetation communities or suites of animal species are important within the general reserves framework, and are highly relevant to issues relating to retention of biodiversity within Australian ecosystems. The M2 Development would encompass large areas of cracking clay environments in the North-East Kimberley and adjacent areas of the Northern Territory. Within this sub-region, the areas associated with the alluvial, cracking clay floodplains of the Ord and Dunham Rivers comprise the majority of land with high pastoral potential (WA Department of Agriculture, 1985).

ecologia Environmental Consultants undertook a biological assessment survey in 1996-97 of the Riverside and M2 Development Areas. Based on an analysis of the floristic data obtained during the survey, it has been the contention that the conservation significance of the proposed development area is high, and therefore suitable areas should be protected as part of any future development.

1.1 SCOPE OF THIS REVIEW

The purpose of this review is to examine and synthesise information pertinent to the M2 Development Area for use by Kinhill Pty Ltd in preparing an Environmental Review and Management Programme for the proposed project. In particular, it updates the ecologia (1997a) report by examining floristic composition in a regional context by taking into consideration the results of subsequent field surveys in the region. The bioregional level is taken to be, for the purposes of this document, the Victoria-Bonaparte bioregion as defined by Thackway and Cresswell (1995) and discussed in Connors et al. (1996). The majority of information discussed refers to sites within this bioregion, although some sites are slightly outside the defined region. Within the bioregion, the vegetation has been examined at four levels: between Land Systems; within the Ivanhoe Land System; within the Ord Basin; and within the M2 Development Area.

Comparisons of the floristic composition of sites within the M2 Development Area, as described in ecologia (1997a), have been made with regional data sets obtained from Agriculture Western Australia. This data relates to the vegetation of rangeland areas in the East Kimberley on Land Systems similar to the Ivanhoe Land System, which is represented in the M2 area. Secondly, a review is given of a vegetation survey undertaken by staff of the Parks and Wildlife Commission of the Northern Territory (PWCNT) (Brocklehurst et al., 1998), and the comparison of these areas of the Ivanhoe Land System with the vegetation detailed in the M2 report (ecologia, 1997a). At a finer level, an analysis has been made of the relationship between the vegetation communities of the M2 area and the Riverside area (incorporating the Mantinea Flats, Carlton Plain and Ivanhoe West areas). Finally, the floristic composition of sites within the three plains of the M2, i.e. the Keep, Knox and Weaber, have been compared.

1.1.1 Regional Approach

A regional approach has been adopted in the preparation of this document, based on the bioregions defined by Thackway and Cresswell (1995). These bioregions provide a nationally acknowledged series of defined areas that represent relatively homogeneous areas in terms of their underlying geology, surface landform and vegetation expression, fauna, and climatic regime. These bioregions represent defined areas that can be examined and utilised in an assessment of representation of biotic components of the landscape within the existing conservation reserves framework. In this instance, floristic communities are to be used as the primary means of determining representation, since the large size of the M2 Development Area precludes a fine scale investigation of the biota.

At the broadest scale, comparisons have been made between the vegetation of similar Land Systems. The Land Systems of the region were described and mapped by a surveying party from the Commonwealth Scientific and Industrial Research Organisation (CSIRO), who investigated the Ord-Victoria Area in 1949 and 1952. The geology, geomorphology, soils and vegetation of the area are described, primarily in the context of pastoral productivity, and a series of 50 Land Systems are indicated. Systems are defined as 'an area or group of areas throughout which there is a recurring pattern of topography, soils, and vegetation' (Stewart et al., 1970). The Ord-Victoria Area, as defined by Stewart et al. (1970), extends from longitude 127°30'E to 132°E and from latitude 13°20'S to 19°S, and is therefore slightly larger than the Victoria-Bonaparte bioregion, incorporating portions of the adjacent Ord-Victoria Plains bioregion. Although relatively old, the Land System categorisation of Stewart et al. (1970) is still used at present as the primary classification of landforms in the region, and has been updated only in areas such as the Ord Irrigation Area, where detailed soil mapping has been undertaken.

A series of Western Australian Rangeland Monitoring System (WARMS) sites from ten of these Land Systems within the East Kimberley are compared with sites from the Riverside and M2 Development Areas in Section 2. These Land Systems consist of several (generally 3 to 6), smaller scale, Land Units. The similarity of the Land Units in which the WARMS sites are located in comparison to Land Units of the Ivanhoe Land System, within which the M2 Development Area lies, are also discussed in Section 2.

The great majority of the M2 Development Area, and the Ord Stage II Area in general, lies within the Ivanhoe Land System of Stewart et al. (1970), hence it is the primary Land System of interest. The major portion of this Land System represents those areas of cracking clay that are considered suitable for irrigated agriculture. The M2 Development Area is surrounded by upland areas of other Land Systems, notably the Cockatoo, Weaber, Pinkerton and Dinnabung Land Systems, that are unsuitable for irrigated agriculture.

Within the Ord-Victoria Area, only a few Land Systems include substantial areas of cracking clays. In addition to the Ivanhoe System, these areas include the Inverway, Wave Hill, Argyle, Hawk, Willeroo, Dillinya and Legune Land Systems. The Ivanhoe Land System, as well as incorporating the major portion of the Ord Stage II Area, includes areas along the Dunham River to the south of the M2 Development Area, a relatively large area in the Victoria River and West Baines River area of the Northern Territory, and scattered locations to the south-east of the M2 Development Area in the vicinity of the WA/NT border, and another series of scattered locations in the western NT.

Ivanhoe Land System areas are therefore widely spread throughout the region, and the underlying geology and climatic conditions of these areas shows some variation, hence we may expect variation in the vegetation and fauna of these areas. It is interesting to note also, that since these areas generally have high stock carrying capacity, they are in the main utilised by pastoralists, and few areas are protected in

reserves. Section 3 of this review examines the composition of the vegetation of the M2 Development Area with vegetation from areas within the Ivanhoe Land System in the Northern Territory on Auvergne and Spirit Hills stations. The information from these areas, collected during a survey by personnel from the PWCNT, pertains to the largest portions of the Ivanhoe Land System within the Northern Territory.

At a finer scale the M2 Development Area and Riverside Areas of the Ord Basin are compared in Section 4. The Ord Basin comprises one of the two main geological formations of the north-east Kimberley, the Ord River originating upstream of the Bungle Bungle Ranges and passing through the Ord Valley, where it is joined by the Dunham River. Aldrick and Moody (1977) have suggested that, possibly in the Tertiary period, the Ord River passed through the Keep River and Weaber Plains, having only relatively recently fallen into its present course. As a result, the M2 Development Area and Riverside Areas are thought to have had relatively similar geological histories, although within different time frames. The underlying geology of the two areas is similar, with both areas incorporating Cainozoic 'black soil', however a greater proportion of the Riverside Area consists of Quaternary alluvium deposited by the (current) Ord River (Geological Survey of WA, 1970).

Within the M2 Development Area, the vegetation of the Keep, Weaber and Knox plains is compared, and the distinctiveness of these areas is assessed (Section 5). The plains of the M2 Development Area occupy different portions of a contiguous drainage system, including the lower reaches of the Keep River (Keep River Plain), an area between Knox Creek, a tributary of the Keep, and the middle portion of the Keep River (Knox Creek Plain), and an area with a seasonally inundated relatively undifferentiated drainage system that lies to the west and slightly upland of the Keep River (Weaber Plain). These areas are, therefore, relatively similar, and lie in close proximity to one another, and the boundaries between them are somewhat arbitrary.

1.1.2 Data Sets

Comparison of data from ecologia (1997a) has been made in the first instance with WARMS data obtained from Natural Resource Management Services, Agriculture Western Australia. Due to the sensitivity of the data, it has been supplied without station or site identifiers. The data relates to WARMS sites in the East Kimberley, and includes Land System and Land Unit information for each site in addition to a species list. This data set applies to cracking clay country on pastoral stations, generally pertaining to grasslands. Additional information supplied includes a map and accompanying list of the sites within three regions from north to south, and the WARMS for Grasslands field manual (Strutt et al., 1995) which details the methodology used.

The second data set examined as part of the review process is detailed in Brocklehurst et al. (1998), 'Reconnaissance Land Resource Survey of Auvergne Station and Sections of Spirit Hills Station, Northern Territory'. This survey was undertaken in 1998, and involved personnel from the PWCNT and the Department of Lands, Planning and Environment (DLPE). A copy of the document, stamped DRAFT, was obtained from Wesfarmers Limited. Information from this document is reviewed, and relevant data examined in Section 3.

The data sets from survey areas in the Ord Stage II Area are detailed in Appendix B of ecologia (1997a). Presence absence data were used in all cases where comparisons were made, since this serves to minimise the effects of between-survey differences in methodology. Site descriptions, including vegetation structure and dominance information, are given in Appendix C of ecologia (1997a). Several assumptions have necessarily been made in these analyses between surveys, the primary one being that species identifications are accurate and comparable. In the case of comparisons within the Ord Stage II Area, consistency has

been maintained since taxonomy is based on Wheeler et al. (1992), and identification of plant material was undertaken by ecologia staff. Comparisons with WARMS data should also be valid, since they also used Wheeler et al. (1992). It is less certain if the Auvergne data is comparable, since it is not clear from their report what nomenclature was used. In an attempt to standardise the various data sets, species lists were examined for nomenclature, species without a specific name were removed where they were present at only one or two sites, and subspecies and varieties were amalgamated into single full species. More detailed descriptions of the data sets, assumptions made, and limitations of the data are given in the following sections.

2.0 WARMS SITE DATA

2.1 INTRODUCTION

A comparison of plant data from Rangeland monitoring sites spread throughout the East Kimberley has been undertaken along with a further comparison with selected sites from the M2 Development Area. The details of these analyses and their findings are the subject of this section.

2.2 WARMS METHODOLOGY

Agriculture Western Australia (AGWest) have established and initiated surveys of a series of Western Australian Rangeland Monitoring System (WARMS) sites in the East Kimberley. A portion of the data relating to the vegetation of WARMS Grassland sites from Land Systems and Land Units (based on Stewart et al., 1970) similar to black soil plain areas has been made available to ecologia Environmental Consultants for independent analysis. All sites are on cracking clay soils in areas north of Halls Creek.

The methodology for surveying WARMS Grassland sites is detailed in Strutt et al. (1995), and will only be summarised here. WARMS sites are aimed at long-term monitoring of rangeland condition and have been established on pastoral leases, in paddocks, ideally near the centre of a relatively large area of a given vegetation type. Sites are marked out and a photo taken from a fixed location. Frequency of perennial species within 100 quadrats (70 cm x 70 cm) are assessed. Quadrat placements are at 2.5 metre intervals along five parallel transects, spaced 6.5 metres apart. Species are recorded as present within a given quadrat, and the frequency score is simply the number of quadrats in which a given species is present. Tree and Shrub crown cover is assessed at six locations along the transect, and is based on the Bitterlich Gauge % crown cover estimate, as described in Strutt et al. (1995).

Sites were surveyed during the dry season, and are located throughout the East Kimberley, from Carlton Hill station in the north to Gordon Downs in the south. The data supplied by AGWest also included Land System and Land Unit information, but due to the 'sensitivity' of the data, it has been coded so that individual sites can not be identified. Species nomenclature used by AGWest follows Wheeler et al. (1992), and longevity information has also been obtained from this source.

2.2.1 Data

Rangeland monitoring data supplied by AGWest is from 37 WARMS sites located within ten of the Land Systems identified for the Ord-Victoria area by Stewart et al. (1970):

<u>Land System</u>	<u>No. of sites</u>
Antrim	5
Argyle	3
Cowendyne	1
Frayne	3
Gordon	1
Inverway	15
Ivanhoe	1
Pinkerton	1
Wave Hill	6
Willeroo	1

These Land Systems include areas described as anything from hilly or rugged stony country to nearly treeless black soil plains, however, only WARMS sites located on land units described as having gentle slopes or on plains have been included in the data set (Table 1). The soils of these areas, as described by Stewart et al. (1970), are predominantly grey and brown cracking clays of the Kununurra, Argyle and Barkly soil families.

Table 1: Land System and Land Unit Information for WARMS monitoring sites.

Descriptions from Lands of the Ord-Victoria Area, WA and NT (CSIRO Land Research Series No. 28)				
SITE CODE	LANDSYSTEM (Number)	LAND UNIT	LAND UNIT DESCRIPTION	SOILS AND VEGETATION
	Description			
WARMS 01 - 05	Antrim (10)	4	Gentle lower slopes and flat ar	Cununurra, Argyle, Barkly-grey and brown cracking heavy clays
	Hilly country associated with igneous rocks			Mitchell and other mid-height grasses <i>Astrebla pectinata</i> , <i>Aristida latifolia</i> .
WARMS 06 - 08	Argyle (43)	1	Very gentle slopes	Argyle, Cununurra - brown and grey cracking clays.
	Medium & small areas of gently undulating			Mitchell and other mid-height grasses <i>Astrebla pectinata</i> ,
	black soil plain			<i>Aristida latifolia</i> .
WARMS 09	Cowendyne (-)	2	cracking clay plains	Not listed
WARMS 10, 12	Frayne (35)	3	Gentle slopes	Cununurra and Barkly - grey & brown cracking heavy clays
WARMS 11	Many small patches scattered	3	plain close to channel	Sparse low woodland <i>Terminalia astrotrata</i> , <i>T. volucris</i> or trees
	undulating to low hilly basalt country			absent <i>Dichanthium</i> spp., <i>Astrebla squarrosa</i> , or mid-height
				grasses <i>A. pectinata</i> , <i>D. fecundum</i> , <i>Panicum</i> spp., <i>Aristida latifolia</i> .
WARMS 13	Gordon (38)	3	Gentle lower slopes	Cununurra, Barkly, Argyle - grey and brown cracking clays
	Low hilly to undulating limestone country			Barley Mitchell mid-height grass <i>Astrebla pectinata</i>
WARMS 14 - 28	Inverway (41)	1	Nearly flat broad plains	Cununurra - grey cracking clays; and Argyle - brown ccs
	Nearly treeless high-level black soil plains			Barley Mitchell mid-height grass <i>Astrebla pectinata</i>
WARMS 29	Ivanhoe (47)	1	Nearly flat plains	Cununurra-grey ccs with small areas of Argyle-brown ccs
	Gently sloping alluvial black soil			Grasses <i>Dichanthium</i> spp., <i>Astrebla squarrosa</i> , <i>Sorghum</i>
	plains with some timbered red soil			<i>stipoideum</i> , <i>Ophiuros exaltatus</i> , <i>Aristida latifolia</i> , with
				fringing forest and tall grasses near stream lines.
WARMS 30	Pinkerton (1)	7	Gentle slopes adjacent to	Elliott and miscellaneous alluvial soils
	Rugged stony country on sedimentary r		streamlines	Euc. woodland with <i>Themeda australis</i> , <i>Sehima nervosum</i> ,
				<i>Chrysopogon fallax</i> , or <i>Sorghum stipoideum</i> .
WARMS 31, 33-36	Wave Hill (42)	3	Moderate to gentle slopes,	Cununurra, Barkly, Argyle - grey and brown cracking clays
WARMS 32	Gently undulating basalt black	3	may be stoney	Mitchell and other mid-height grasses <i>Astrebla pectinata</i> ,
	soil country			<i>Dichanthium fecundum</i> , <i>Panicum</i> spp.
WARMS 37	Willeroo (45)	3	Moderate to gentle slopes	Cununurra and Argyle - grey & brown cracking clays
	Numerous small areas of basalt black			Blue grass tall grass <i>Dichanthium</i> spp., <i>Sorghum</i> spp.,
	soil plains with tall pastures			<i>Eulalia fulva</i> , <i>Ophiuros exaltatus</i> .

Data supplied by AGWest includes a list of perennial species and significant semi-perennials and annuals. Species lists for individual sites are relatively short, with from six to 23 species, and most sites having between nine and 13 species recorded, including usually multiple species of (perennial) grass, a few shrubs, and one or two tree species. The low number of species recorded is presumably a reflection of the nature of the sites (i.e. grasslands) and the timing of the surveys in the dry season when perennial species are often the only (identifiable) plant species present. These surveys are relevant in the context of rangeland monitoring, since tropical pastures consist chiefly of summer-growing perennial grasses, and stocking rate is determined by the carrying capacity in the dry season (Bryan, 1970). However, it does not provide a full floristic assessment of the plant species present (particularly annuals), since a large number of flora species occur only during the wet season.

2.2.2 Analysis

Analysis of the relationships between WARMS survey sites was conducted using the cluster analysis component of the computer program Systat. Systat is a statistical analysis software package that performs cluster analysis operations to produce a quantitative index of dissimilarity for each site relative to every other site, ultimately constructing a hierarchical ordering of sites in the form of a dendrogram that shows the relative similarities between sites. The analysis detects natural groupings of data and summarises the hierarchical relationships within the dataset by quantifying the degree of similarity of sites in terms of species composition.

Species presence/absence data were used in the cluster analyses of the WARMS sites (Appendix A1). Frequency data obtained from AGWest was converted to presence absence data and cluster analysis was performed on this data for the complete species list. A second analysis of the presence absence data was undertaken concentrating on unequivocal (adequately identified) and purely perennial species, thus reducing the size of the dataset. Dendrograms were constructed using the Pearson correlation complete linkage method (Wilkinson, 1989).

2.3 RESULTS OF ANALYSES

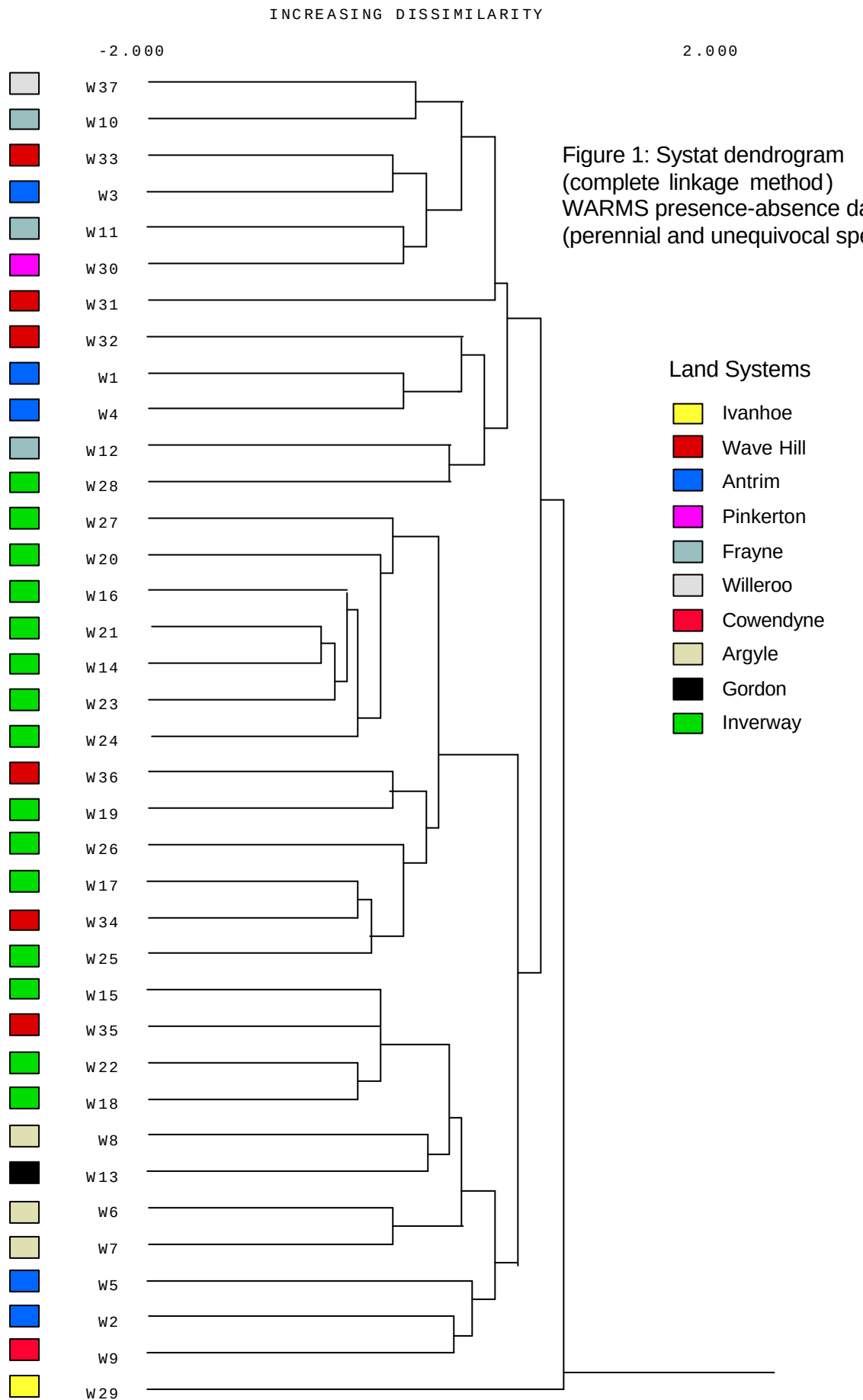
Analysis of the complete dataset and the refined presence absence data resulted in dendrograms illustrating the relationship of the WARMS sites (Figures 1 and 2). In both instances the broad relationships and clustering of sites within the hierarchy are similar, hence the two datasets will be discussed together.

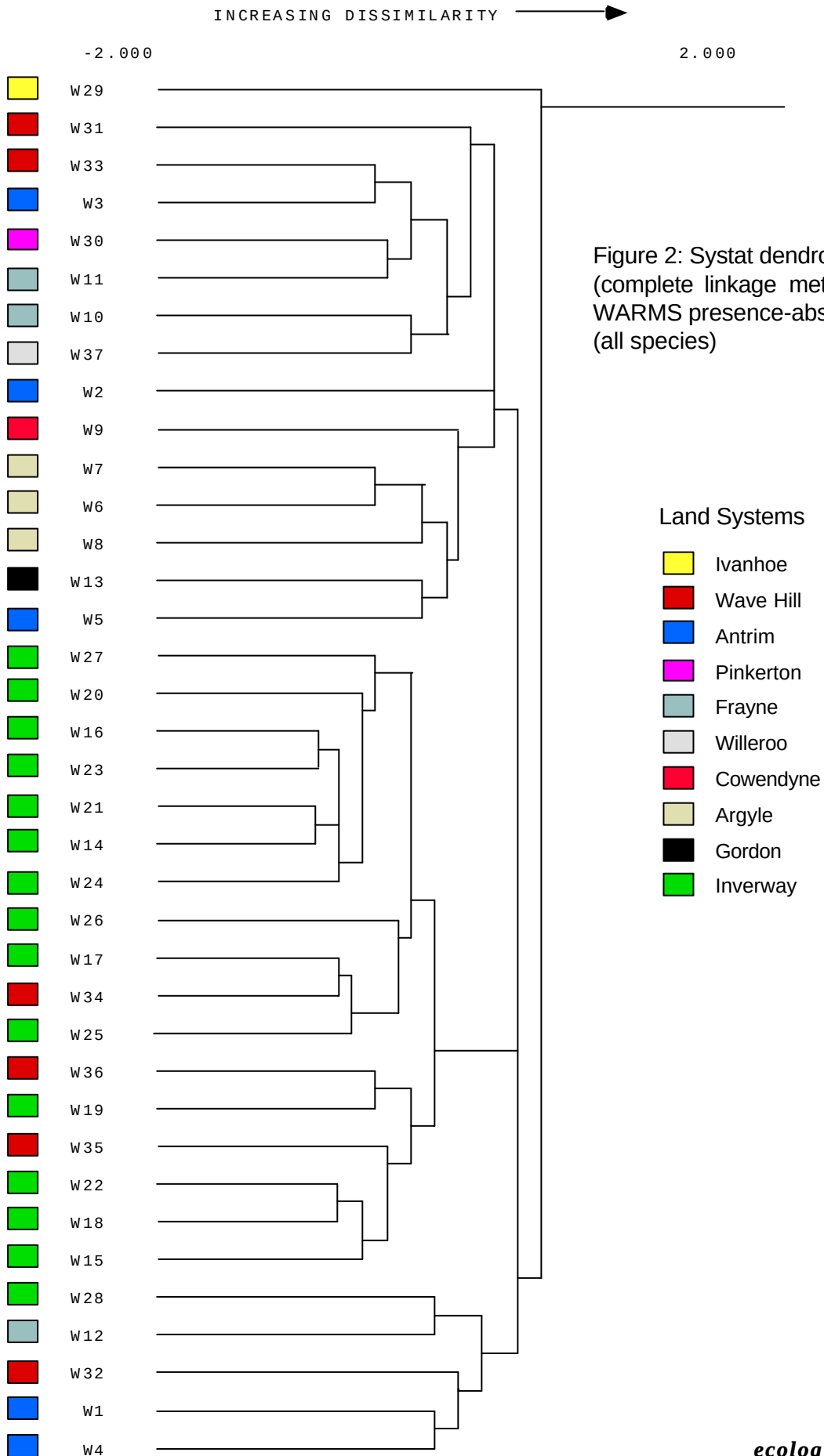
The first and most obvious feature of the hierarchy is the clear separation of Site W29 from the remainder of the sites. Although Site W29 is located at the base of the dendrogram in the refined dataset (Figure 1) and at the apex in the complete dataset (Figure 2), the relationship with all other sites is identical. This site is from the Ivanhoe Land System, and is clearly distinct from all other WARMS sites in the analysis, indicating that the composition of the vegetation at this site is noticeably at variance with the other sites.

Further relationships evident within the dendrogram include the broad clustering of the Inverway sites. In the complete dataset these sites form a distinct subset of the data, intermixed with several Wave Hill sites, with Site W28 the only site separated from the main cluster. A similar, although slightly less clear-cut relationship is evident in the dendrogram based on the refined dataset.

The three Argyle sites are also very closely clustered in the two dendrograms, indicating close similarity between these sites. The single site from the Gordon Land System, Site W13, is also associated with these Argyle sites.

Finally, the single Cowendyne site clusters with the Antrim sites W2 and W9, although this relationship is more clearly demarcated in the refined dataset analysis (Figure 1).





2.4 DISCUSSION

The clear separation of the Ivanhoe site from all other sites in the analysis suggests that the black soil plain areas of this Land System are significantly different in floristic composition from the other areas examined as part of this analysis. Examination of the raw data indicates that certain species that were widespread throughout the majority of WARMS sites were not recorded from the Ivanhoe site, including the grasses *Aristida latifolia*, *Chrysopogon fallax*, *Iseilema vaginiflorum* and *Panicum decompositum*, and several species of Mitchell Grass *Astrebla* spp. Of these species, only *Iseilema vaginiflorum* is considered to be an annual (Wheeler et al., 1992).

It is unfortunate that the Ivanhoe data is restricted to a single site, since this suggests the possibility that the clear separation of this site from all others is due to a chance effect or an anomaly in the data, despite the consistent methodology employed by AGWest in the acquisition of the data. It seems evident, however, that the overall analysis is quite robust, since the general relationships of the sites, and their separation according to Land System as outlined above, suggests that the data is adequate. Additionally, other Land Systems represented by single sites were not clearly separated in the analysis, indicating that the Ivanhoe site is indeed unique.

Use of presence absence data may in some instances weaken the ability of the cluster analysis to clearly determine the relationship of sites, since it represents a loss of information and an imposed uniformity on the data. However, in this instance the Ivanhoe site is clearly separated from the other sites, hence further indicating the real nature of these apparently strong differences in species composition.

2.5 COMPARISON OF WARMS SITES AND ECOLOGIA SITES

A further comparison was made using Systat cluster analysis techniques to examine the relationship between the floristic composition of the 37 WARMS sites, and a series of similar sites surveyed during the biological assessment of the proposed Ord Stage II development area undertaken by ecologia Environmental Consultants.

Biological assessment survey sites selected for the analysis were Grassland communities on black soil plain areas within the Keep, Knox, Weaber, Carlton and Ivanhoe West Bank areas of the proposed development. A total of 15 sites were selected, and only dry season data was used so as to make the data comparable. As in the previous analysis, annual species were omitted, as were those species that were not adequately identified. Taken together, it was hoped that the datasets would be relatively similar, despite differences in survey technique. To further simplify matters, only presence absence data were used. The data from the two surveys were combined in a species by site matrix (Appendix A2) and a Systat cluster analysis undertaken utilising the complete linkage (farthest neighbour) method.

2.5.1 Results

The dendrogram generated from the analysis showed a relatively clear separation of the ecologia sites from the WARMS sites (Figure 3). This initial impression gained from examination of the dendrogram suggests that the ecologia sites are different from the WARMS sites, therefore seeming to indicate either a real difference in the vegetation or an artefact generated from the survey techniques employed.

However, a more detailed examination of Figure 3 reveals that, in fact, the first level of separation divides several of the ecologia sites from the remainder of the sites, including the WARMS sites. This suggests that the data resulting from the two different surveys are comparable, since there is considerable integration of

the sites within the framework of the dendrogram. The single ecologia site CP47 is also found to be amongst the WARMS sites, further indicating that integration of the two datasets is valid. Site CP47 is on a cracking clay soil plain at the eastern end of Carlton Plain, and relatively few species were recorded from this site. In common with many of the WARMS sites, *Aristida latifolia*, *Chrysopogon fallax*, *Dichanthium fecundum*, *D. sericeum* and *Panicum decompositum* were recorded at this site.

It is interesting to note, therefore, that WARMS Site W29, the site on the Ivanhoe Land System, is amongst the ecologia sites that are separated at the first level of the cluster diagram. This suggests that the vegetation of this area is similar to other survey sites on the Ivanhoe Land System, yet it is distinct from the great majority of the WARMS sites in other areas of the Kimberley on similar landforms and soils but within different Land Systems. Plant species recorded from several ecologia sites that were also recorded at Site W29 include *Excoecaria parvifolia* and *Phyllanthus maderaspatensis*, whereas this site lacks grasses recorded at other WARMS sites such as *Aristida latifolia*, *Astrebla elymoides*, *Chrysopogon fallax* and *Iseilema vaginiflorum*.

The second level of separation divides the majority of the ecologia sites (the exception being Site CP47) from the remaining WARMS sites. This suggests that there is a difference in floristic composition between these areas, and that the differences are consistent between survey sites. In particular, the species *Abelmoschus ficulneus*, *Eragrostis tenellula*, *Hibiscus panduriformis*, *Iseilema fragile* and *Sida spinosa* were recorded commonly at ecologia sites, but were recorded infrequently or not at all at WARMS sites.

Within the cluster of ecologia sites, it is evident also that there is some differentiation between the M2 Development Area and Riverside Areas, since the cluster of ecologia sites at the second level of separation includes M2 Development Area sites only, whereas the cluster at the first level of separation is composed of Riverside sites, with the exception of Site KR13.

2.6 CONCLUSIONS

Systat cluster analysis of WARMS site data from the East Kimberley indicate that the vegetation of the Ivanhoe Land System is distinct from other Land Systems with cracking clay plains. The primary floristic differences are in certain species of perennial grasses that were not recorded from the Ivanhoe Land System, but were recorded within many other areas. Given that the WARMS data from within the Ivanhoe Land System is restricted to a single site, it would be useful to obtain further information from sites within this Land System in order to perform a more rigorous regional analysis.

Further analysis of the WARMS sites in comparison to a series of similar grassland sites surveyed by ecologia in the Ord Stage II Area indicates that there is separation of WARMS sites from the Ord sites. This appears to be due to a real difference in vegetation, rather than an artefact due to differing methodology. An interesting finding of this analysis is that WARMS Site W29, located within the Ivanhoe Land System, clusters with the Ord Riverside sites.

Ord Stage II: M2 Development Area
Regional Biodiversity and Representation

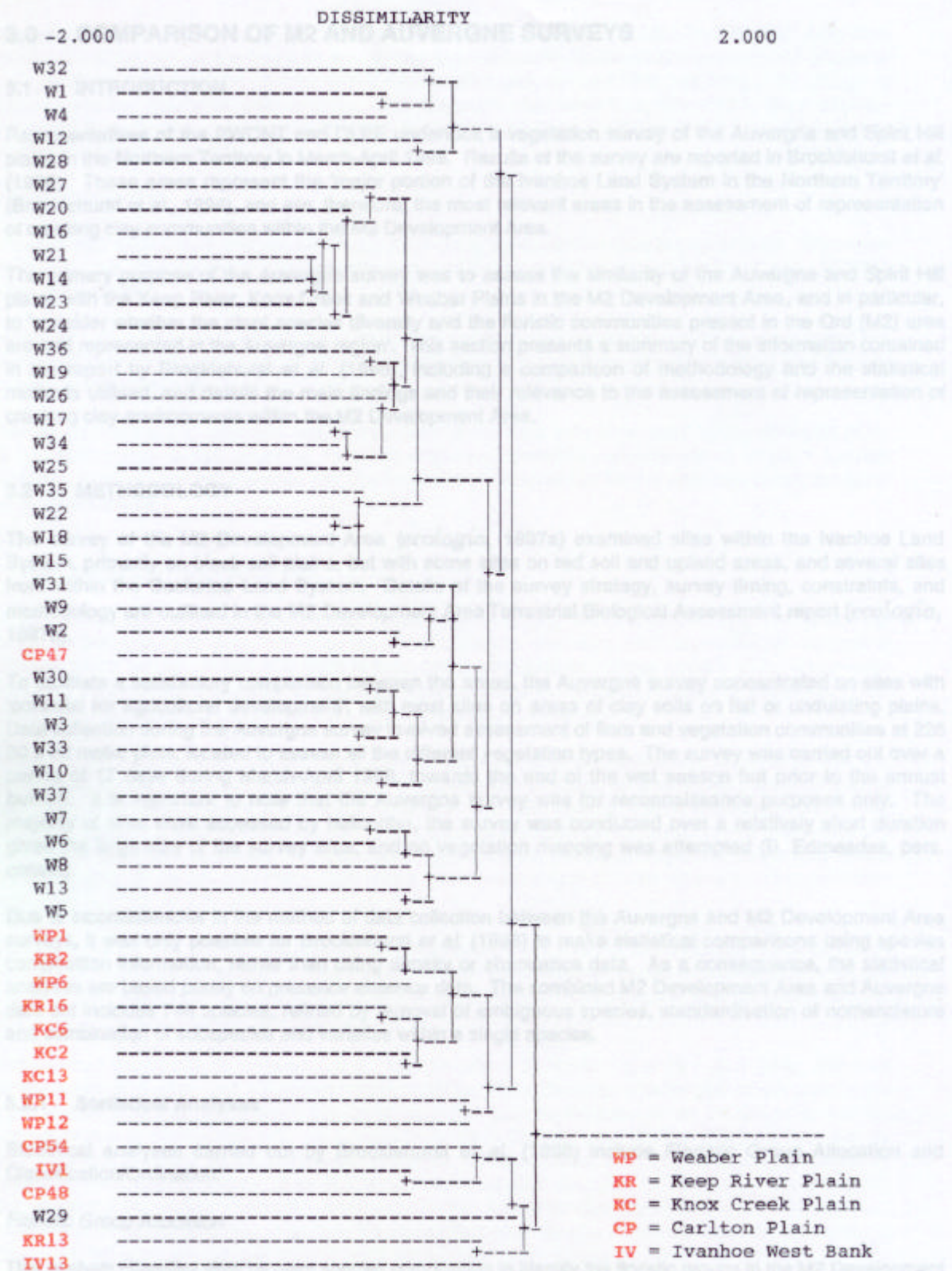


Figure 3: Systat dendrogram (complete linkage method)
WARMS Sites (plain text) and *ecologia* Ord Sites (**bold**)

3.0 COMPARISON OF M2 AND AUVERGNE SURVEYS

3.1 INTRODUCTION

Representatives of the PWCNT and DLPE undertook a vegetation survey of the Auvergne and Spirit Hill plains in the Northern Territory in March-April 1998. Results of the survey are reported in Brocklehurst et al. (1998). These areas represent the 'major portion of the Ivanhoe Land System in the Northern Territory' (Brocklehurst et al., 1998), and are, therefore, the most relevant areas in the assessment of representation of cracking clay communities within the M2 Development Area.

The primary purpose of the Auvergne survey was to assess the similarity of the Auvergne and Spirit Hill plains with the Keep River, Knox Creek and Weaber Plains in the M2 Development Area, and in particular, to 'consider whether the plant species diversity and the floristic communities present in the Ord (M2) area are well represented in the Auvergne region'. This section presents a summary of the information contained in the report by Brocklehurst et al. (1998), including a comparison of methodology and the statistical methods utilised, and details the main findings and their relevance to the assessment of representation of cracking clay environments within the M2 Development Area.

3.2 METHODOLOGY

The survey of the M2 Development Area (ecologia, 1997a) examined sites within the Ivanhoe Land System, primarily on black soil plains, but with some sites on red soil and upland areas, and several sites from within the Cockatoo Land System. Details of the survey strategy, survey timing, constraints, and methodology are outlined in the M2 Development Area Terrestrial Biological Assessment report (ecologia, 1997a).

To facilitate a satisfactory comparison between the areas, the Auvergne survey concentrated on sites with 'potential for agricultural development', with most sites on areas of clay soils on flat or undulating plains. Data collection during the Auvergne survey involved assessment of flora and vegetation communities at 226 20 x 20 metre plots, located to assess all the different vegetation types. The survey was carried out over a period of 17 days during March-April 1998, towards the end of the wet season but prior to the annual burnoff. It is important to note that the Auvergne survey was for reconnaissance purposes only. The majority of sites were accessed by helicopter, the survey was conducted over a relatively short duration given the large size of the survey area, and no vegetation mapping was attempted (B. Edmeades, pers. comm.).

Due to inconsistencies in the method of data collection between the Auvergne and M2 Development Area surveys, it was only possible for Brocklehurst et al. (1998) to make statistical comparisons using species composition information, rather than using density or abundance data. As a consequence, the statistical analyses are based purely on presence absence data. The combined M2 Development Area and Auvergne data set includes 744 species, refined by removal of ambiguous species, standardisation of nomenclature and combination of subspecies and varieties within a single species.

3.2.1 Statistical Analyses

Statistical analyses carried out by Brocklehurst et al. (1998) include Floristic Group Allocation and Classification/Ordination:

Floristic Group Allocation

This analysis classifies sites by plant species composition to identify the floristic groups in the M2 Development Area, using the 'Czeckanowski similarity measure and the non-hierarchical clustering routine ALOC'. Sites from the Auvergne survey are then tested to determine if they can be validly allocated to one of these groups, or if they should join an additional group, by allocating sites to groups according to their 'distance' from the group centroid, controlled by the 'allocation radius'. The analysis of the M2 Development Area data was carried out at two levels, the first with a relatively large allocation radius (0.95) resulting in 6 groups or 'broad vegetation types', and the second with a smaller allocation radius (0.85), resulting in 17 groups or 'more homogeneous vegetation communities'. The Auvergne sites were then allocated to the previously defined groups from the two levels of classification, or were placed in an additional group if the distance was greater than the allocation radius.

Classification/Ordination

Classification with multivariate analysis was carried out using the combined data set for all sites. Sites were classified using the 'Czeckanowski similarity measure and the hierarchical agglomerative routine UPGMA'. 14 groups were defined.

Ordination was also used to examine the relationship between the combined series of sites, using the 'Czeckanowski similarity measure and multidimensional scaling'. A four dimensional ordination was required to obtain an acceptable stress level.

The primary limitations and concerns with comparison of the data sets expressed by Brocklehurst et al. (1998) are differences in the sampling methods employed, possible inconsistencies in plant species identifications between the two surveys, and the (necessary) requirement for the analyses to rely solely on presence absence data.

3.3 RESULTS AND COMPARISONS

A total of 512 flora taxa were collected during the Auvergne survey. Brocklehurst et al. (1998) divide the vegetation of the Auvergne area into a series of associations, including 15 Grassland and Sedgeland associations, and a variety of open woodland to open forest associations (canopy cover > 2%). These latter associations include areas dominated by (number of associations in brackets) Acacia (2), Eucalyptus (17), Excoecaria (2), Lysiphyllum (2), Melaleuca (7), Terminalia (5) and 'other' (2).

The overlap in the species lists from the two survey areas is low, and Brocklehurst et al. consider that it is 'lower than expected considering the geographic proximity and similarity in land types'. Only 35% (264 species) of taxa were recorded from both survey areas, with 286 species (38%) recorded from the M2 Development Area only, and 194 species (26%) restricted to the Auvergne survey. Broad similarities are evident in the data, for example many of the more common families, genera and species are common to the two areas, however, there are also many differences, most noticeably in species diversity and composition (Table 2).

Possible reasons for the greater number of species recorded in the M2 Development Area (682) as opposed to the Auvergne survey (512) may relate to either methodology, survey timing and effort, or are attributable to real differences in floristic diversity. Consideration of these reasons, and an examination of their influence on floristic diversity, are given below.

The methodology adopted by Brocklehurst et al. (1998) involved the utilisation of 20 x 20 m plots, and a full floristic assessment of sites was attempted where possible. The generally smaller size of the plots in the Auvergne survey may partially explain the lower recorded species richness when compared to the M2 Development Area, in comparison with the general focus on collection in the M2 Development Area survey and less restriction to clearly demarcated plots. However, as Brocklehurst et al. (1998) point out, it does not adequately explain the discrepancy, given the 'large number of sites surveyed and the aim to sample all the variation within the vegetation' during the Auvergne survey. A greater diversity of land types within the M2 Development Area would also help to explain the higher recorded species richness, however, the reality of the situation is that a greater number of land types were investigated during the Auvergne survey.

Table 2: Comparison between the M2 Development Area and Auvergne botanical surveys.

	M2 Development Area	Auvergne
Number of survey sites	86 in dry 45 in wet	226 in late wet
Number of flora taxa	682 overall 418 in dry	512 overall
Number of families recorded	87	82
Number of genera recorded	276	244
Families with most taxa: (Number of taxa in brackets)	Poaceae (133) Fabaceae (63) Cyperaceae (44) Myrtaceae (30) Convolvulaceae (28)	Poaceae (100) Fabaceae (47) Cyperaceae (56) Myrtaceae (27) Mimosaceae (22)
Genera with most taxa: (Number of taxa in brackets)	<i>Fimbristylis</i> (18) Cyperus (15) Acacia (14) Ipomoea (12) Eucalyptus (11) Goodenia (11)	<i>Fimbristylis</i> (23) Acacia (15) Eucalyptus (14) Goodenia (12) Cyperus (10) Terminalia (9)
Most widely distributed species:	<i>Lysiphyllum cunninghamii</i> <i>Chrysopogon fallax</i> <i>Themeda triandra</i> <i>Eucalyptus microtheca</i> <i>Iseilema fragile</i> <i>Panicum decompositum</i>	<i>Sorghum bulbosum</i> <i>Chrysopogon fallax</i> <i>Lysiphyllum cunninghamii</i> <i>Eriachne obtusa</i> <i>Sehima nervosa</i>

Survey timing will partially determine the number of species recorded, since there are many annual and facultative perennial species in the Kimberley that are either absent or extremely difficult to identify during the dry season, particularly in the latter stages of the dry when the land becomes parched. The M2 Development Area survey included both a dry season and a wet season survey. Although the wet season survey was limited in duration, the focus on collection and the large number of annual species present facilitated detailed assessment of many of the vegetation communities. The Auvergne survey was conducted towards the end of the wet season, before the annual burnoff, hence it would be expected that the majority of species would be present and suitable for collection and identification, and in fact the

majority of sites were visited 'as they were drying out' (A. Fisher, pers. comm.). Survey timing and effort, therefore, may also partially explain the differences in species richness, since a greater period of time was spent in the M2 Development Area. However, a similar suite of species, including annuals present only during the wet season, were recorded during both surveys, suggesting that other factors are involved. Additionally, the majority of the M2 Development Area survey effort was expended during the dry season.

The final conclusion that seems unavoidable, after investigation of the various factors that contribute to recorded species richness, is that the greater number of species recorded in the M2 Development Area is founded upon a real effect. A possible reason is that the differences may relate to greater landform diversity in the M2 Development Area, although from the information available this possibility is not substantiated. This suggests, therefore, that hydrological (drainage, inundation effects) or edaphic (soil-related) factors are likely to be the major determinants at a local scale. At a regional scale, the pronounced effect of the rainfall gradient from north to south on the vegetation composition in the Ord-Victoria region described by Perry (1970), may be important. Regardless of the origins of the high plant species diversity in the M2 Development Area, the value of this biological diversity should be taken into account in the planning of future developments.

3.3.1 Results Of Statistical Analyses

Floristic Group Allocation

6-Group level

The majority of Auvergne sites could be allocated to one of the six groups ('broad vegetation types') derived from the M2 Development Area data, with only 17 Auvergne sites (7.5%) not allocated. Most M2 Development Area sites were classified into Group 5, representing sites generally of grassland on cracking clay, and consisting predominantly of dry season sites (Table 3). A relatively large number of Auvergne sites were allocated to Group 5, however, many Auvergne sites were also allocated to Group 2, which may reflect the greater variety of land units surveyed and fewer cracking clay sites in the Auvergne survey area (Brocklehurst et al., 1998).

Table 3: Summary of 6-group level allocation.

Group	No. of M2 sites	No. of Auv. sites*	Landform and Soils	Vegetation	Comments
1	28	9	cracking clays	Characterised by sedges and herbs in understorey.	Mostly wet season sites, many annuals
2	25	79	red-browns; hills; Cc LS peripheral	Frequently <i>Heteropogon contortus</i> , <i>Cayratia trifolia</i> , <i>Eucalyptus confertiflora</i> , <i>Grewia retusifolia</i> .	Many Auv. sites. Reflects more non cracking clay sites
3	3	2	rivers, creeks; inundated; saline	<i>Xerochloa</i> , <i>Trianthema</i> , <i>Sesbania cannabina</i> , <i>Panicum decompositum</i> . <i>Avicennia</i> , <i>Halosarcia</i> , etc.	Few sites. Many halophytes.
4	8	11	red-browns; Cc LS; peripheral	Unique species include <i>Acacia hemiglaucula</i> , <i>Drosera ordensis</i> , <i>Senna artemisioides</i>	Marginal land units
5	56	87	cracking clays; other	Frequently <i>Chrysopogon fallax</i> , <i>Lysiphyllum cunninghamii</i> , <i>P. decompositum</i> , <i>Aristida latifolia</i> , <i>Themeda</i> , <i>Sida</i> , <i>Sorghum</i> , <i>Ophiuros</i>	Most M2 sites Mostly dry season Most Auv. sites

6	10	19	creek & wetland margins	Frequently <i>Excoecaria parvifolia</i> and <i>Eucalyptus microtheca</i>	Mainly creeks and waterholes
n =	130	224			

* Auvergne sites allocated to M2-derived groups, with 17 Auvergne sites allocated to 4 additional groups.
KEY: No. = Number; Auv. = Auvergne; Cc LS = Cockatoo Land System

Brocklehurst et al. (1998) have made several comments concerning the information summarised in Table 3, the most relevant being that they feel that Group 1, given that it consists primarily of M2 Development Area wet season sites, is presumably the wet season equivalent of Group 5, but the large number of annual species collected during the wet season has sufficiently biased the data so that the sites fall out in separate groups. In some cases, there may be identical sites surveyed during both the dry and wet season that have been classified in this analysis into Group 5 and Group 1.

Group 3 consists of very few sites, both for the M2 area and Auvergne, and includes inundated areas and saline sites, supporting halophytic species such as Saltbush *Halosarcia* sp. and mangroves *Avicennia* spp. Group 6 primarily includes wetland and riverine sites and their margins, including species characteristic of seasonally inundated sites such as Gutta-Percha Tree *Excoecaria parvifolia* and Flooded Box *Eucalyptus microtheca*.

17-Group level

At the 17 group level, due to the more homogeneous nature of the groups and the smaller allocation radius, the allocation of Auvergne sites was less successful, with 85 sites (38 %) allocated to additional groups. In particular, no Auvergne sites were allocated to Groups 2, 3, 4 and 7, and Groups 5 and 8 had only a single Auvergne site allocated. Characteristics of the groups with no or few sites allocated are detailed below (Table 4).

Table 4: Characteristics of Groups with poor allocation of Auvergne sites.

Group	Characteristics

2	On scattered rocky hills or outcrops. Similar communities in the Auvergne area may not have been sampled.
3	Generally woodlands bordering rivers or waterholes, often subject to inundation. Vegetation variable, 'defined by herbs and twiners in the ground layer'.
4	Single M2 Development Area site, a mixed species woodland on red soil.
7	Single M2 Development Area wet season site with some infrequently recorded ground layer species.
5	Sites adjacent to rivers with halophytic species.
8	Sites on sandy soils adjacent to hills or on the Cockatoo Land System.

The greatest number of M2 Development Area sites were placed in Group 11 (38 sites), which consists of cracking clay sites with, characteristically, *Lysiphyllum cunninghamii* in the upper storey and *Iseilema fragile*, *Chrysopogon fallax* and *Aristida latifolia* in the ground layer. A fairly large number of Auvergne sites were

also allocated to Group 11. The second largest number of M2 Development Area sites were placed in Group 1. They are primarily wet season sites and are poorly represented by Auvergne sites.

Classification

A total of 14 groups were derived from a classification of the combined M2 Development Area and Auvergne data sets. Brocklehurst et al. (1998) noted a 'tendency for sites from the two surveys to divide into separate groups'. Three of the groups (Groups 4, 7 & 12) contain sites only from the Auvergne survey areas, and Group 10 only includes M2 Development Area sites. M2 Development Area sites also represent less than 3 % of the sites in Groups 3 and 13. Groups 8, 10 and 14 were dominated by M2 Development Area sites, with few Auvergne sites. Pertinent floristic information for these Groups is given in Table 5.

Table 5: Floristics of groups dominated by M2 Development Area sites.

Group	Frequent species	Unique species
8	<i>Phyllanthus maderaspatensis</i> , <i>Commelina ensifolia</i> , <i>Cyanotis axillaris</i> , <i>Cyperus microcephala</i>	<i>Euphorbia kimberleyensis</i>
10	-	<i>Digitaria brownii</i> , <i>Tricosanthes cucumerina</i>
14	<i>Chrysopogon fallax</i> , <i>Iseilema fragile</i> , <i>Panicum decompositum</i> , <i>Aristida latifolia</i> , <i>Sorghum timorense</i> , <i>Hibiscus panduriformis</i> , <i>Lysiphyllum cunninghamii</i> , <i>Sida spinosa</i> , <i>Brachyachne convergens</i>	-

Statistical analysis of the distribution of the sites within the group classification derived by Brocklehurst et al. (1998), using the contingency table chi-square test, suggests that there is a significant difference ($p < 0.001$, $df = 13$) in the proportion of sites within the groups. This tendency for the sites to segregate between groups within the classification suggests an intrinsic difference between the majority of sites in the two survey areas.

Ordination

Ordination of the M2 Development Area and Auvergne sites, based on the first and second axis of a four-dimensional ordination, indicates a tendency for the M2 Development Area and Auvergne sites to occupy different areas of the ordination space. There is considerable overlap between the sites, however M2 Development Area sites tend to occupy the top and left portions of the ordination space, whereas Auvergne sites are generally lower. There is a wide spread of Auvergne sites, suggesting that they 'incorporate most of the total variation in vegetation composition found in the two surveys'. The greater diversity of land types surveyed during the Auvergne survey may have contributed to this spread of sites.

3.4 CONCLUSIONS

The primary findings of the report by Brocklehurst et al. (1998) in relation to the M2 Development Area can be summarised as follows:

- i. Plant species diversity and vegetation communities of the M2 Development Area and Auvergne areas were compared.
- ii. The greater variety of vegetation communities identified during the Auvergne survey may reflect the greater variety of land types surveyed.
- iii. The greater number of plant species recorded during the M2 Development Area survey, including 38% of the combined species only from the M2 Development Area, may be based upon a real effect, rather than methodology or survey timing.
- iv. Broad vegetation types (6-group level) were represented in both survey areas.
- v. Seven of the 17 vegetation communities from the M2 Development Area were not or poorly represented in the Auvergne survey, although six of these are associated with non-clay soils that may not have been sampled during the Auvergne survey.
- vi. There are broad similarities in the vegetation of the two areas, but also evidence of real floristic differences.
- vii. A limited survey in the M2 Development Area using the Auvergne methodology (or vice versa) may help to clarify the floristic relationships.

Particular reference should be made to several of these points. Firstly, the greater biodiversity in the M2 Development Area does not appear to be a direct result of differences in survey methodology or timing between the Auvergne and M2 Development Area surveys, although these may have been contributing factors. Both surveys involved collection of annual species during the wet season in addition to records of perennial grasses and woody species, and were aimed at covering the diversity of vegetation within the survey area, hence similar species richness would be expected.

Secondly, although broad vegetation types were represented in both the Auvergne and M2 Development Area survey areas, finer scale associations were not well represented. This finding indicates that more detailed information on vegetation associations is required not only for the Ord area, but also for other areas within the Victoria-Bonaparte bioregion, since the information available at present is at a very coarse scale, and is fragmentary. Further vegetation survey work within the M2 Development Area to delineate vegetation communities is vital in order to facilitate accurate mapping and detailed assessment of representation, and hence conservation values.

4.0 COMPARISON OF M2 AND RIVERSIDE DEVELOPMENT AREAS

4.1 INTRODUCTION

This section describes an analysis made of the relationship between the vegetation communities of the M2 Development Area, including the Keep River, Knox Creek and Weaber Plains, and the Riverside Development Area, incorporating the Mantinea Flats, Carlton Plain and Ivanhoe West Bank areas.

Systat cluster analysis was used to determine the relationship between the sites based on flora species presence absence data. A combined species by site table was formulated based on all the dry season survey sites, and a similar procedure was followed as in earlier analyses whereby the data set was standardised and subspecies and varieties were amalgamated into single species.

The methodology used in these surveys is described in detail in ecologia (1997a, 1997b).

4.2 RESULTS AND INTERPRETATION

The Systat dendrogram derived from the combined Ord data indicates separation of the M2 Development Area and Riverside Development Area sites at the extremes of the dendrogram, and intermingling of the sites within the middle portion (Figure 4). The top half is dominated by M2 Development Area sites and the bottom half by Riverside sites. Where there is apparent intermingling, it is also noticeable that there is clumping of sites where they are from the same area.

Looking first at the series of 26 sites at the top of the dendrogram, it is evident that a single Riverside Development Area site, CP47, is clustered with a series of M2 Development Area sites. Examination of the M2 Development Area site descriptions indicates that these sites are predominantly on black soil plains, and many of them are on areas of soil type 1, Cununurra normal phase. Other sites are on related soil types such as 1c or 1g, or are on aquitaine phase soils, types 5a and 5b. The vegetation at these sites is characterised by an overstorey of *Lysiphyllum cunninghamii*, often with *Eucalyptus microtheca* and *Excoecaria parvifolia*, presumably on wetter or seasonally inundated sites. The understorey frequently includes *Chrysopogon fallax*, other common grasses including *Themeda triandra*, *Panicum decompositum* and *Aristida latifolia*. These sites are generally described as open woodlands over grassland, although there are two purely Grassland sites. Site CP47, the single Riverside site, is a cracking clay plain grassland of *Dichanthium fecundum*, *Aristida latifolia* and *Chrysopogon fallax*. All these grass species are present at the M2 Development Area sites, and as mentioned, *C. fallax* is particularly common.

The next grouping consists of 18 sites which includes ten M2 Development Area and eight Riverside Development Area sites. The M2 Development Area sites are predominantly from the Weaber Plain whereas the Riverside Development Area sites are mixed. The M2 Development Area sites include a series of sites that are transitional, lying at the margin of rock outcrops or at the edge of the black soil plain. A series of soil types are represented, including 4a and 4b (cracking clays in depressions), 7b (eroded cracking clays adjacent to creeks and rivers), and 8a (soil complex at the edge of upland areas). These soils are generally in patches, or are at the periphery of the black soil plain.

The vegetation of the Riverside Development Area sites is similar to the M2 Development Area sites, common species in both areas including *Lysiphyllum cunninghamii*, *Chrysopogon fallax*, *Aristida latifolia*, *Dichanthium fecundum*, *Iseilema fragile*, *Carissa lanceolata* and *Panicum decompositum*. The M2 Development Area sites generally include *Themeda triandra* and *Ophiuros exaltatus* as dominant species in the grass layer, with an overstorey of *Lysiphyllum cunninghamii*, *Corymbia bella* and other species.

Dichanthium fecundum is commonly encountered in the grass layer of the Riverside sites, with the overstorey including *Lysiphyllum cunninghamii* and *Acacia farnesiana*.

The intermediate clusters are a mixture of M2 Development Area and Riverside Development Area sites, and no clear picture emerges from an examination of soil type, landforms, or dominant vegetation.

Figure 4: Systat dendrogram (complete linkage method)
M2 and Riverside presence absence data
 M2 sites in plain text, Riverside in red

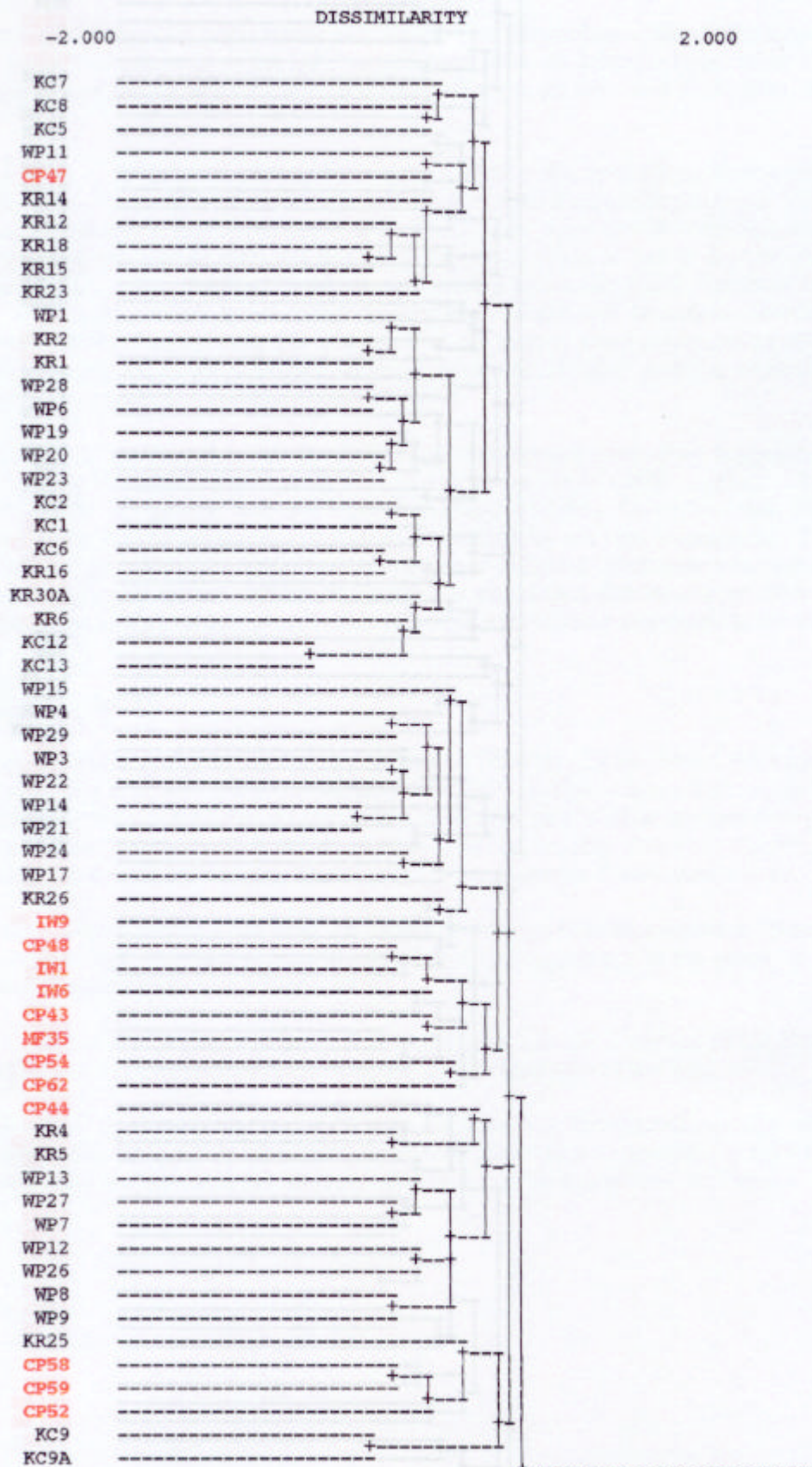
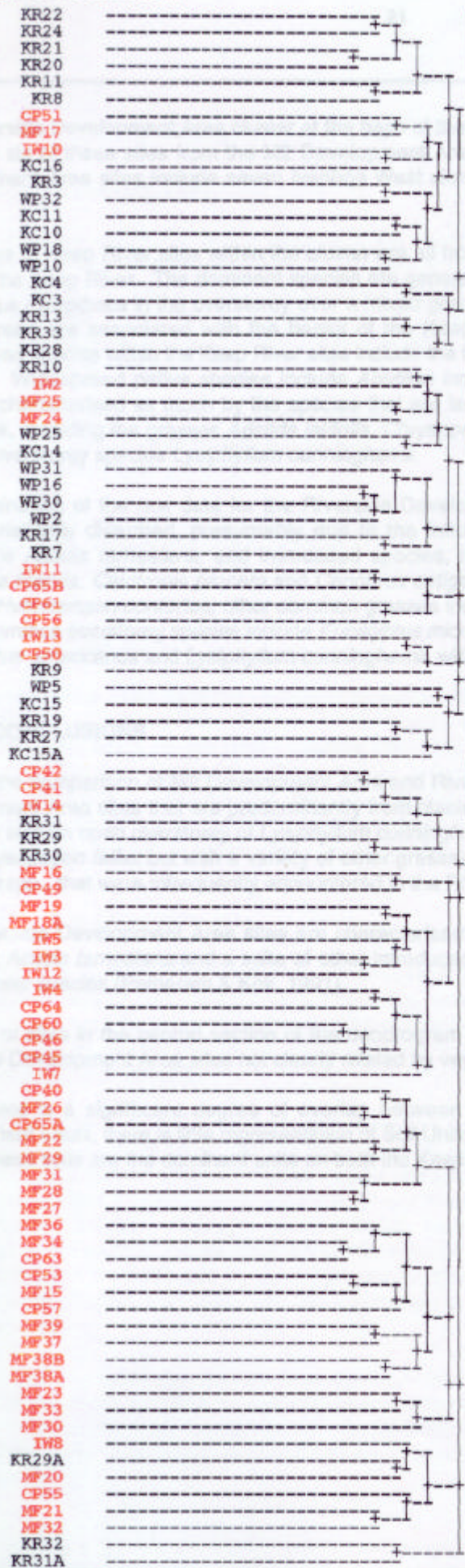


Figure 4: continued.



The Riverside Development Area cluster at the base of the Systat dendrogram includes a series of 48 sites, with only six of these sites from the M2 Development Area, all from the Keep River Plain. The Riverside Development Area sites include seven Ivanhoe West sites, 22 Mantinea Flats sites, and 13 Carlton Plain sites.

The series of Keep River sites within the cluster are all from the northern or north-eastern part of the plain close to the Keep River. The dominant species are generally *Excoecaria parvifolia*, *Melaleuca nervosa* and *Eucalyptus microtheca* in the overstorey over a mixed grass layer, or with chenopod shrubs at Site KR31A. These areas are associated with the banks of the Keep River or are in former channels of the river. Widespread species within the Keep River sites include the introduced plants *Passiflora foetida* and *Calotropis procera*. Widespread native species include *Abutilon indicum* and *Melaleuca nervosa*. These sites are perhaps characterised as much by the species that are lacking when compared to other M2 Development Area sites, including the grasses *Aristida latifolia*, *Chrysopogon fallax*, *Iseilema fragile* and *Sehima nervosa*, and the overstorey species *Lysiphyllum cunninghamii*.

An examination of the raw data for the Riverside Development Area sites suggests that these sites are characteristically disturbed, presumably due to the influence of cattle grazing. The most widespread species is *Acacia farnesiana*, and introduced species, including *Aerva javanica*, *Parkinsonia aculeata*, *Passiflora foetida*, *Calotropis procera* and *Cenchrus setigerus* are also widespread. The most widespread grass is *Heteropogon contortus*, other common grasses including *Dichanthium fecundum* and *Chrysopogon fallax*. Common overstorey species include *Eucalyptus microtheca*, *Excoecaria parvifolia*, *Adansonia gregorii*, *Gyrocarpus americanus* and *Lysiphyllum cunninghamii*, with *Carissa lanceolata* in the midstorey.

4.3 CONCLUSIONS

Overall, the comparison of M2 Development Area and Riverside Development Area sites separates the M2 Development Area sites that are predominantly from black soil plain areas into Group 1, consisting of sites generally with an open overstorey of *Lysiphyllum cunninghamii* and other species over grassland, commonly with *Chrysopogon fallax* but with a variety of other grasses, notably *Themeda triandra*, *Aristida latifolia* and *Sorghum* spp., that were infrequently encountered in the Riverside Development Area.

The Riverside Development Area sites are characterised by species present in degraded, grazed areas, including *Acacia farnesiana* and a suite of other introduced species, and the grass *Heteropogon contortus*, an increaser species (Petheram & Kok, 1991).

A series of sites in the central section of the dendrogram include a mixture of M2 Development Area and Riverside Development Area sites not clearly related by vegetation or soil type.

While there is a significant degree of overlap between the floristic composition of sites from the two development areas, there is little representation of Soil Units 1 and 5 vegetation in the Riverside Development Area. These soils are the dominant units on both the Keep River and Weaber Plains.

5.0 COMPARISONS WITHIN THE M2 DEVELOPMENT AREA

5.1 INTRODUCTION

This section describes cluster analysis of the vegetation at survey sites within the M2 Development Area, involving those on the Keep River, Knox Creek and Weaber Plains. This represents the finest scale of the analyses so far, and serves to compare the vegetation of the areas that are most likely to be impacted by the proposal. The areas are in close proximity to each other and it is therefore expected that the vegetation associations will be similar, varying with local scale factors such as soil type, surface geology and landform, and drainage.

Systat cluster analysis was used to determine the relationship between the M2 Development Area sites based on flora species presence absence data. A species by site table was formulated based on all the dry season survey sites.

The methodology used in the M2 Development Area survey is described in detail in ecologia (1997a). The preference of plant species for certain soil or substrate types as described in this section are based on information from Petheram and Kok (1991) and Wheeler et al. (1992).

5.2 RESULTS

Systat cluster analysis of the vegetation at survey sites within the M2 Development Area resulted in a broad separation into two groups (Figure 5). The first group can be designated in a general fashion as including sites on the black soil plain with cracking clay soils of the normal (Type 1) and aquitaine (Type 5) phase, cracking clays in depressions (Type 4), and associated areas of creeks, channels and other seasonally inundated areas. The second group includes those sites lying on other, generally patchy soil types, including red soils, hills of sandstone and dolomite and sites underlain by these rocks, former channels and river banks, and sandy soils. These two subgroups are discussed separately below.

5.2.1 Black Soil Plain Sites

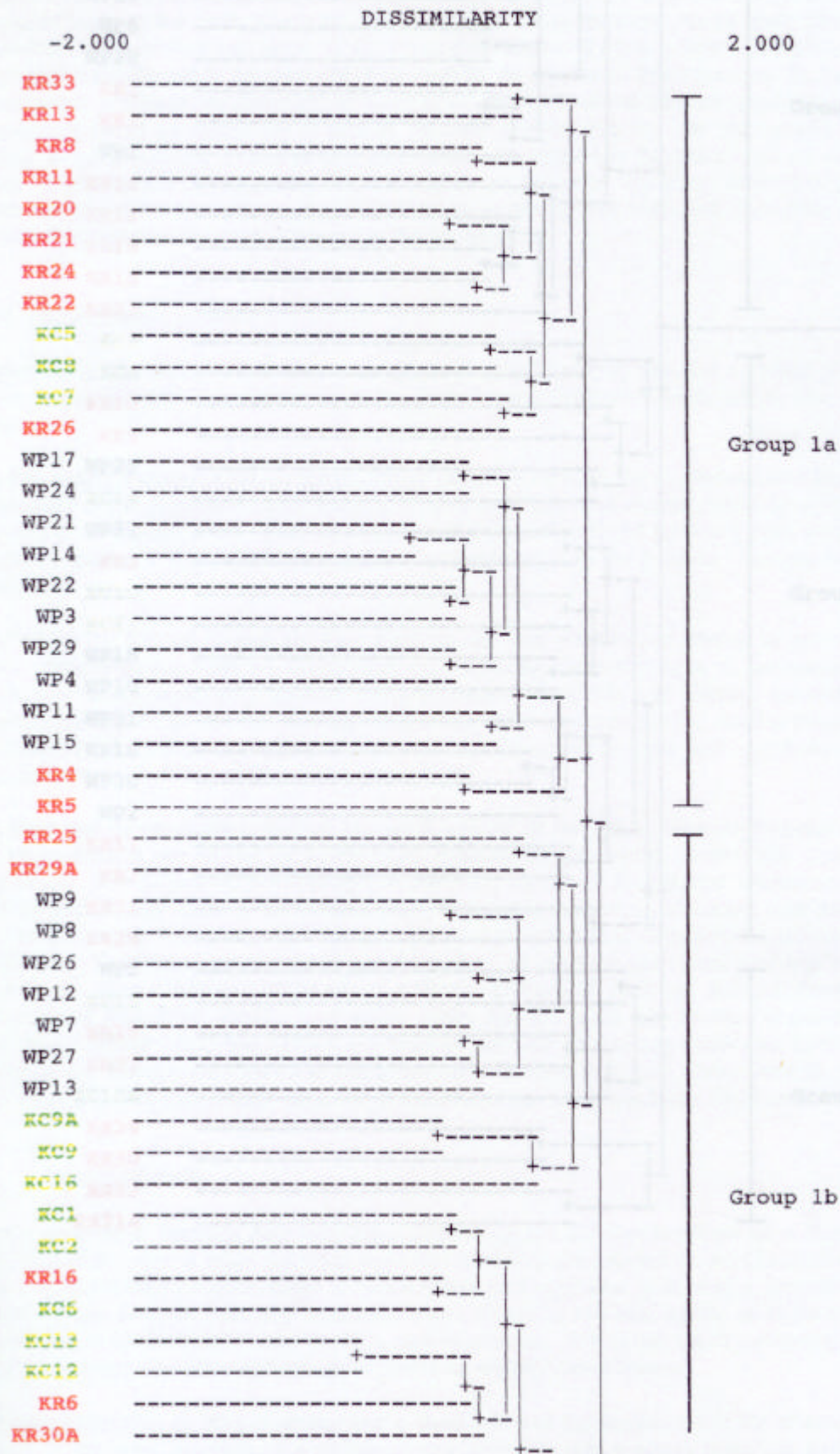
Within the cluster of black soil plain sites, there are two main groups, 1a and 1b. Within Group 1a are a series of sites on black soil plains that generally have cracking clay soils that are not normal phase cracking clays (soil type 1). The soils in these areas predominantly include soil types 4 (cracking clays in depressions) and 5 (aquitaine cracking clays), with a series of other soil types associated with black soil plains or lying at the margin of the plains.

The vegetation of the Group 1a areas commonly consists of *Lysiphyllum cunninghamii* in the overstorey, with a grass layer dominated by species such as *Themeda triandra*, *Chrysopogon fallax* and *Sehima nervosum*. Other commonly encountered species include the trees *Eucalyptus microtheca*, *Terminalia oblongata* and *Corymbia bella*, shrubs such as *Carissa lanceolata* and *Acacia bidwillii*, and grasses *Ophiuros exaltatus*, *Aristida latifolia* and *Iseilema fragile*. Further subdivision of Group 1a suggests that the series of sites at the head of the dendrogram are from black soil plain areas with depressions, whereas the second subdivision is dominated by sites that are marginal to the black soil plain, or in areas that intergrade between different soil types. The first subdivision is dominated by Keep River sites, the second by Weaber Plain sites.

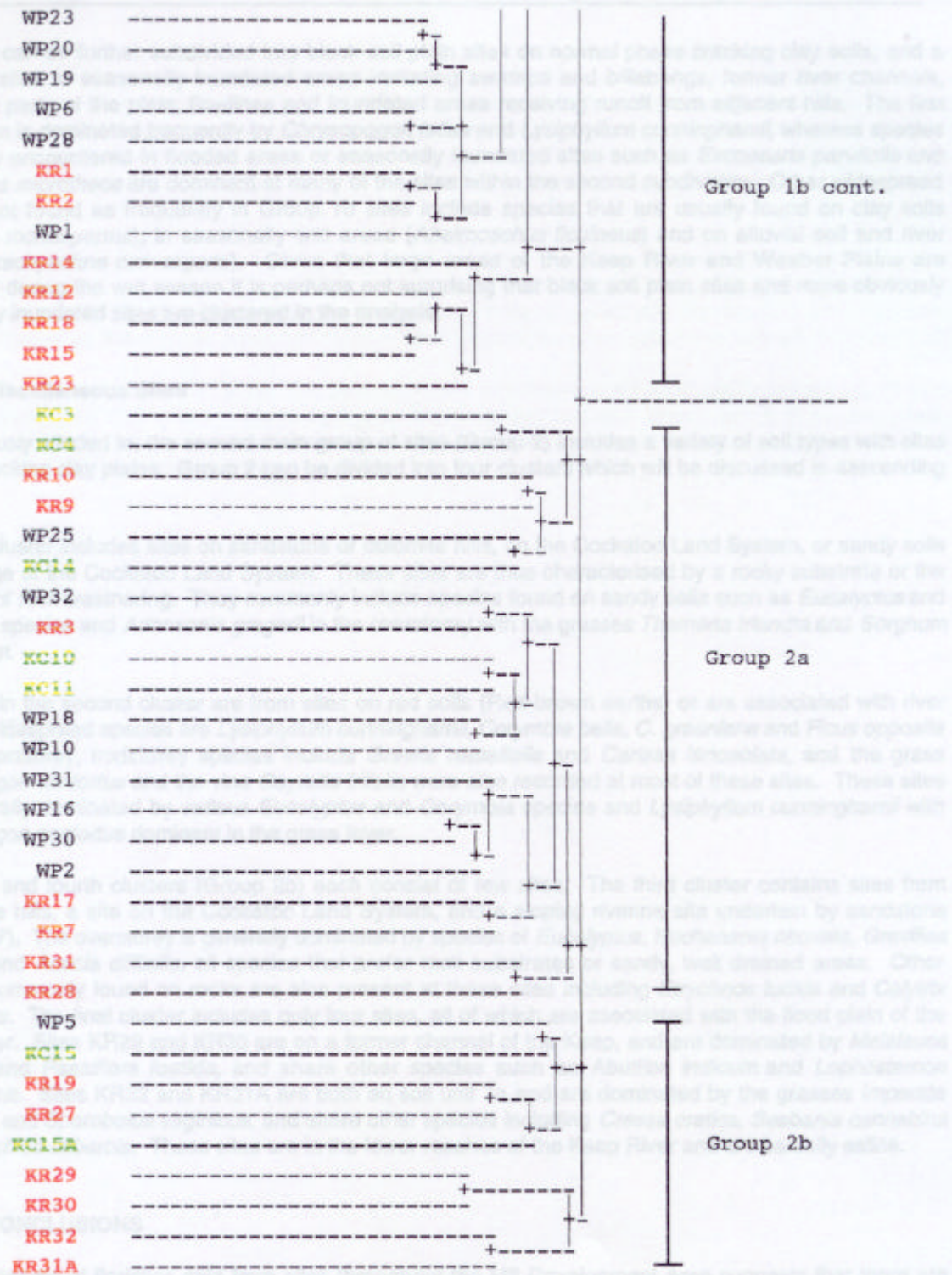
Group 1b contains sites that are more clearly of the black soil type, with many of the dominant plant species similar to those in Group 1a, but in different proportions. The most widespread species in these

sites are the grasses *Panicum decompositum*, *Aristida latifolia* and *Iseilema fragile*. Widespread overstorey species are similar to those in Group 1a and include *Excoecaria parvifolia*, *Lysiphyllum cunninghamii* and *Eucalyptus microtheca*.

**Figure 5: Systat dendrogram (complete linkage method)
M2 presence absence data**



Ord Stage II: M2 Development Area
Regional Biodiversity and Representation



Group 1b can be further subdivided into black soil plain sites on normal phase cracking clay soils, and a series of sites in seasonally inundated areas including swamps and billabongs, former river channels, inundated parts of the plain, flowlines and inundated areas receiving runoff from adjacent hills. The first subdivision is dominated frequently by *Chrysopogon fallax* and *Lysiphyllum cunninghamii*, whereas species commonly encountered in flooded areas or seasonally inundated sites such as *Excoecaria parvifolia* and *Eucalyptus microtheca* are dominant at many of the sites within the second subdivision. Other widespread species not found as frequently in Group 1b sites include species that are usually found on clay soils (*Neptunia monosperma*), in seasonally wet areas (*Abelmoschus ficulneus*) and on alluvial soil and river banks (*Brachyachne convergens*). Given that large areas of the Keep River and Weaber Plains are inundated during the wet season it is perhaps not surprising that black soil plain sites and more obviously seasonally inundated sites are clustered in the analysis.

5.2.2 Miscellaneous Sites

As previously alluded to, the second main group of sites (Group 2) includes a variety of soil types with sites not on cracking clay plains. Group 2 can be divided into four clusters which will be discussed in descending order.

The first cluster includes sites on sandstone or dolomite hills, on the Cockatoo Land System, or sandy soils at the edge of the Cockatoo Land System. These sites are thus characterised by a rocky substrate or the products of rock weathering. They commonly include species found on sandy soils such as *Eucalyptus* and *Corymbia* species and *Adansonia gregorii* in the overstorey with the grasses *Themeda triandra* and *Sorghum stipoides*.

Sites within the second cluster are from sites on red soils (Red-brown earths) or are associated with river banks. Widespread species are *Lysiphyllum cunninghamii*, *Corymbia bella*, *C. greeniana* and *Ficus opposita* in the overstorey, midstorey species include *Grewia retusifolia* and *Carissa lanceolata*, and the grass *Heteropogon contortus* and the vine *Cayratia trifolia* were also recorded at most of these sites. These sites are generally dominated by various *Eucalyptus* and *Corymbia* species and *Lysiphyllum cunninghamii* with *Heteropogon contortus* dominant in the grass layer.

The third and fourth clusters (Group 2b) each consist of few sites. The third cluster contains sites from sandstone hills, a site on the Cockatoo Land System, and a sloping riverine site underlain by sandstone (Site KR27). The overstorey is generally dominated by species of *Eucalyptus*, *Buchanania obovata*, *Grevillea agrifolia* and *Acacia difficilis*, all species that prefer rock substrates or sandy, well drained areas. Other species commonly found on rocks are also present at these sites including *Strychnos lucida* and *Calytrix exstipulata*. The final cluster includes only four sites, all of which are associated with the flood plain of the Keep River. Sites KR29 and KR30 are on a former channel of the Keep, and are dominated by *Melaleuca nervosa* and *Passiflora foetida*, and share other species such as *Abutilon indicum* and *Lophostemon grandiflorus*. Sites KR32 and KR31A are both on soil unit 7a and are dominated by the grasses *Imperata cylindrica* and *Sporobolus virginicus*, and share other species including *Cressa cretica*, *Sesbania cannabina* and *Xerochloa imberbis*. These sites are in the lower reaches of the Keep River and are partially saline.

5.3 CONCLUSIONS

Cluster analysis of floristics data from sites throughout the M2 Development Area suggests that there are two broad categories of sites, the black soil plain sites that are located on the Cununurra clay normal phase soils and associated cracking clays in depressions and aquitaine soils, and a second series of sites on a

miscellaneous array of soils and substrate types including red soil, sandy or stony substrates or upland areas such as the Cockatoo Land System, and riverbanks. Within the 'black soil' group, one cluster of sites includes swamps and other seasonally or permanently inundated areas.

This broad grouping of sites is similar to the description of the vegetation of the Weaber Plain provided by Dixon (1996), who recognised a series of concentric zones inwards from the perimeter, outer areas characterised by Aquitaine phase soils (Unit 5) grading to Cununurra normal phase soils (Unit 1) in inner areas. From the outer perimeter, generally treeless grasslands occur on Unit 5c soils, followed by *Eucalyptus tectifica* and *Excoecaria parvifolia* over grasses on Unit 5a soils, more variable vegetation on Unit 5b, and in the interior of the plain Unit 1 where *Lysiphyllum cunninghamii* becomes the dominant overstorey species with generally treeless areas in the centre of the plain with *Sorghum* spp. grasses dominating (Dixon, 1996). Dixon (1996) considers that these changes in vegetation most likely reflect the drainage, and seasonal inundation is presumably a major determinant. Where a stream or river passes across the plain the broad pattern is broken.

Dixon (1996) further recognises the distinctiveness of the vegetation on the scattered areas of red soils on the plain. Grasses include *Heteropogon contortus* and *Themeda triandra*, and Eucalypts are common in the overstorey. Within the current analysis, sites with red soils clustered with riverine sites and sites over sandy or stony soils, these areas representing vegetation outside the broad pattern described by Dixon (1996).

Cracking clay ('black soil') areas are most amenable to irrigated agriculture and therefore are most likely to be developed during the proposed project. Development of these areas needs to be examined in the context of vegetation communities and their representation and the extent of each soil unit (and sub-unit) over the M2 Development Area.

6.0 GENERAL CONCLUSIONS

6.1 INTRODUCTION

The proposed development of the M2 Area will affect significant areas of black soil plain country in the East Kimberley and adjacent Northern Territory in an area that is poorly known biologically. Consequently, environmental issues must be carefully considered to ensure maintenance of biological diversity and protection of biological values. Due to the limited extent of the Ivanhoe Land System in the East Kimberley and the distinctive nature of the vegetation in the M2 Development Area, it is desirable that adequate representation of these areas be maintained. Adequate assessment of the flora and vegetation of the project area is necessary to provide comprehensive information on species diversity and the array of vegetation communities that occur.

Knowledge of the biota of the Victoria-Bonaparte bioregion is relatively poor, with few surveys of flora and fauna. This lack of knowledge is due presumably to the inaccessible nature of much of the region, the low population density, and the fact that few experienced observers have undertaken detailed studies. Most information available that is pertinent to the M2 Development Area is at a very broad scale, including vegetation (Beard, 1979), landforms (Stewart et al., 1970) and soils (Aldrick & Moody, 1977; Dixon, 1996; Schoknecht & Grose, 1996). There are few records of the fauna of the area with the exception of opportunistic data from the Kimberley Research Station. This situation has been remedied to some degree by undertaking a biological survey of the area (ecologia, 1997a).

This document has been prepared in order to examine the vegetation of the M2 Development Area in a bioregional context. The bioregional level is taken to be the Victoria-Bonaparte bioregion, and the majority of information discussed refers to sites within this area. Within this bioregion the vegetation has been examined at four levels at diminishing spatial scales:

1. Between Land Systems within the East Kimberley;
2. Between areas of the Ivanhoe Land System within the Victoria-Bonaparte bioregion;
3. Between the M2 and Riverside Areas within the Ord Basin; and
4. Between the three plains that make up the M2 Area itself.

A summary of the findings within the context of these spatial scales is given below, followed by a discussion of their implications and the main conclusions that have been reached.

6.2 COMPARISONS

6.2.1 Land Systems within the East Kimberley

The floristic composition of a series of 37 WARMS sites located within ten of the Land Systems identified for the Ord-Victoria area by Stewart et al. (1970) were compared. Areas located on land units described as having gentle slopes or on plains were included, since they were considered sufficiently similar to the black soil plains of the M2 Development Area to warrant comparison. The soils of these areas are described as predominantly grey and brown cracking clays of the Kununurra, Argyle and Barkly soil families.

The great majority of the M2 Development Area, and the Ord Stage II Area in general, lies within the Ivanhoe Land System. Within the Ord-Victoria Area, relatively few Land Systems include substantial areas of cracking clays, and they are in the main utilised by pastoralists, with few areas protected in reserves. A clear separation of the Ivanhoe site from all other sites in the analysis suggests that the black soil plain areas of this Land System possess a different floristic composition to the other areas examined. Unfortunately, the WARMS Ivanhoe data is restricted to a single site, making it difficult to come to any firm conclusions.

A further comparison was made between the floristic composition of the 37 WARMS sites, and a series of 15 similar sites within the Keep, Knox, Weaber, Carlton and Ivanhoe West Bank areas of the proposed Ord Stage II. Analysis indicated a generally clear separation of WARMS sites from the Ord sites. This separation appears to be due to real floristic differences rather than an artefact of differing methodology. The single WARMS site located within the Ivanhoe Land System clustered with the Ord sites, and, significantly, with the Carlton Plain sites which are from a similar location.

6.2.2 Ivanhoe Land System Areas within the Victoria-Bonaparte Bioregion

A report on a reconnaissance land resource survey by NT Government personnel (Brocklehurst et al., 1998) compared the composition of the vegetation of the M2 Development Area with vegetation from areas within the Ivanhoe Land System in the Northern Territory on Auvergne and Spirit Hills stations, the largest portions of the Ivanhoe Land System within the Northern Territory. Their aim was to 'consider whether the plant species diversity and the floristic communities present in the M2 Development Area are well represented in the Auvergne region'. To facilitate a satisfactory comparison between the areas, the NT survey concentrated on sites with 'potential for agricultural development', with most sites on areas of clay soils on flat or undulating plains.

The primary findings relevant to the proposed M2 Development Area are that the greater variety of vegetation communities identified during the NT survey may reflect the greater variety of land types surveyed, and the greater number of plant species recorded during the M2 Development Area survey was not thought to be due to differences in survey methodology or timing, and therefore is presumably based on a real effect. The reasons behind the greater observed biological diversity in the M2 Development Area are unclear. Broad vegetation types were represented in both survey areas, however, finer scale vegetation communities from the M2 Development Area were not well represented in the NT survey. Overall, there are considered to be broad similarities in the vegetation of the two areas, but also significant and real floristic differences.

6.2.3 M2 Development Area and Riverside Areas within the Ord Basin

The M2 Development Area and Riverside Development Areas are thought to have had relatively similar geological histories, although within different time frames. The underlying geology of the two areas is similar, with both areas incorporating Cainozoic 'black soil' plains of the Ivanhoe Land System, however, the distribution and coverage of soil types differs between the two areas.

Cluster analysis of plant presence absence data from all dry season sites within the M2 Development Area and Riverside Development Area was undertaken. The analysis separated the M2 Development Area sites that are predominantly from black soil plain areas into a broad group characterised by sites generally with an open woodland of *Lysiphyllum cunninghamii* and other species over grassland, commonly with *Chrysopogon fallax* but with a variety of other grasses, notably *Themeda triandra*, *Aristida latifolia* and *Sorghum* spp.. Sites with a similar array of species were infrequently encountered in the Riverside

Development Area. The M2 Development Area sites are generally on Unit 1 and 5 soils, which include the broad areas of Cununurra normal phase soils and associated wetter areas on the black soil plains. The assumption is that similar areas are poorly represented within the Riverside Development Area, with a single site from Carlton Plain falling within this group. Vegetation of the black soil plains of the M2 Development Area seem thus to form a distinct unit.

The Riverside Development Area sites, at the other extreme, are characterised more by plant species indicative of degraded, grazed areas, including *Acacia farnesiana* and other introduced species, and the grass *Heteropogon contortus*, an increaser species. These grazing effects may have obscured the true relationship between the vegetation of the two areas. Between the extremes of the M2 Development Area black soil sites and the degraded Riverside Development Area sites there is considerable overlap of M2 Development Area and Riverside Development Area sites, and the vegetation may be considered broadly similar.

Poor differentiation of sites within the cluster diagram may indicate that insufficient sites have been surveyed to adequately detail the vegetation. This would appear to be the case based on the poor correlation between vegetation associations and soil type. An alternative possibility is that there are a very large number of associations in the area with characteristic species composition, hence this heterogeneity of the vegetation has been depicted in the separation of sites within the dendrogram. In either case, further investigations into the flora and vegetation of the M2 Development Area are required to refine knowledge of vegetation composition and distribution of vegetation associations.

6.2.4 Weaber Plain, Keep River Plain and Knox Creek Plain within the M2 Area

The floristic composition of the three plains within the M2 Development Area was compared. It is at the finest scale of the analyses, and serves to compare the vegetation of the areas that will be impacted in the M2 Development Area. It should be noted that while the plains of the M2 Development Area have been considered separately for the purposes of the soil surveys undertaken previously, they occupy different portions of a contiguous drainage system and therefore the boundaries between them are to a degree arbitrary. Consequently, it is expected that the vegetation associations will be relatively similar, varying with local scale factors.

Cluster analysis divided the M2 Development Area into two broad categories which are referred to as black soil plain sites and patch sites. The 'black soil plain' cluster of sites includes a group with sites typically on normal phase cracking clay soils (Unit 1), and a second group generally with soils other than these, predominantly including soil types 4 (cracking clays with microrelief) and 5 (Aquitaine cracking clays), with a series of other soil types associated with the plains or lying at their margins.

A series of miscellaneous sites includes black soil plain periphery and upland areas (Units 8, 8a, 8b, and 11, and Cockatoo Land System), riverine woodland along Keep River, Border Creek and lower Knox Creek (Units 7a & 7b), rock outcrops of dolomite, sandstone or limestone (Units 6, 6a, 6b, 6d & 6e), and billabongs and permanent wetlands (Unit B/s).

Sites on areas of red-brown earths are generally well drained and are characterised by distinctive vegetation with an overstorey of Eucalypts (Dixon, 1996). These areas include Soil Units 2a, 2b, 2c and 2d. Soil Units 4a, 4b, 4c, 4d and 4e show considerable microrelief including shelves and depressions. The depressions are generally poorly drained and become inundated during the wet season.

The first group of the more typical 'black soil plain' sites includes sites on the poorly drained Aquitaine phase soils (Soil Units 5a, 5b, 5c), swamps and lagoons and their margins. The second group of black soil

plain sites are predominantly from Soil Unit 1. The vegetation is quite variable, although generally a low woodland over grassland. The most widespread association has *Lysiphyllum cunninghamii* as the dominant species in the overstorey over *Chrysopogon fallax* grassland. Further more detailed investigation of these areas is necessary in order that a more comprehensive analysis can be undertaken, including an assessment of the representation of vegetation communities in relation to the reserves system of the Victoria-Bonaparte bioregion.

More detailed information is required not only for the Ord area, but also for other locations within the bioregion. The information available at present is at a very coarse scale, is limited in scope, and is fragmentary. Further investigation of species of conservation value identified in the M2 Development Area should be undertaken to assess representation of these species and the communities of which they form a part within the Kimberley and adjacent Northern Territory. This should be achieved prior to further development to ensure protection and maintenance of biological diversity.

6.2.5 Conclusions

Several general conclusions can be derived from the analyses of floristic composition at the four spatial scales referred to in this section:

- A) At the Land System level within the East Kimberley, sites on the Ivanhoe Land System differ significantly from all other Land Systems with cracking clay soils.
- B) A comparison of the M2 Development Area with other areas of the Ivanhoe Land System within the Northern Territory indicates that there is a higher plant species diversity within the M2 Development Area. In addition, whilst there are broad scale similarities in the vegetation of the two areas, at a finer scale vegetation community or association level, there are clear differences.
- C) Comparison of the M2 Development Area and Riverside Development Areas, indicates that again whilst there are broad similarities in vegetation types and overlap in floristic composition between these two areas, the two development areas are dominated by distinctly different community types. Significantly, there is no representation of the vegetation communities which occur on major Soil Units 1 and 5 of the M2 Development Area within the Riverside Development Area.
- D) Finally, the vegetation of the M2 Development Area can be broadly divided into black soil plain sites and sites on other soil types. There is a differing degree of representation of these community types on each of the three plains.

REFERENCES

- Aldrick, J.M. and Moody, P.W. 1977. Report on the Soils of the Lower Weaber and Keep Plains, N.T. Animal Industry and Agriculture Branch, Department of the Northern Territory, Darwin.
- Brocklehurst, P., Harwood, B., Hill, J., Edmeades, B. and Fischer, A. 1998. Reconnaissance Land Resource Survey of Auvergne Station and Sections of Spirit Hills Station, Northern Territory.
- Bryan, W.W. 1970. Tropical Pastures. In: ed. G.W. Leeper. The Australian Environment. 4th edition. CSIRO, Victoria.
- Connors, G., Oliver, B. and Woinarski, J. 1995. Bioregions in the Northern Territory: conservation values, reservation status and information gaps. Parks and Wildlife Commission of the Northern Territory, Palmerston, NT.
- Dixon, J. 1996. Soils of the Weaber Plain East Kimberley Western Australia. Resource Management Technical Report No. 152. Agriculture Western Australia.
- ecologia Environmental Consultants. 1997a. M2 Development Area Terrestrial Biological Assessment. Unpublished report commissioned by the Department of Resources Development.
- ecologia Environmental Consultants. 1997b. Riverside Development Area Terrestrial Biological Assessment. Unpublished report commissioned by the Department of Resources Development.
- Geological Survey of Western Australia. 1970. Cambridge Gulf 1: 250,000 geological survey series sheet. Reprinted 1989. Geological Survey of Western Australia, Perth.
- Petheram, R.J. and Kok, B. 1991. Plants of the Kimberley Region of Western Australia. UWA Press, Nedlands.
- Schoknecht, N. and Grose, C. 1996. Soils of the Knox Creek Plain East Kimberley Western Australia and Northern Territory. Resource Management Technical Report No. 153. Agriculture Western Australia.
- Stewart, G.A., Perry, R.A., Paterson, S.J., Traves, D.M., Slatyer, R.O., Dunn, P.R., Jones, P.J. and Sleeman, J.R. 1970. Lands of the Ord-Victoria Area, Western Australia and Northern Territory. CSIRO Australia. Land Research Series No. 28. Melbourne.
- Strutt, S., Handasyde, T. and Beurle, D. 1995. The Western Australian Rangeland Monitoring System for Grasslands. Field Manual. Agriculture Western Australia.
- Thackway, R. and Cresswell, I.D. 1995. An interim biogeographic regionalisation for Australia. ANCA, Canberra.
- Western Australian Department of Agriculture. 1985. Maps Showing Pastoral Potential in the Kimberley Region, Western Australia. Notes for Map Sheet 1. WA Department of Agriculture, Rangeland Management Branch.
- Wheeler, J.R., Rye, B.L., Koch, B.L. and Wilson, A.J.C. 1992. Flora of the Kimberley Region. WA Herbarium, Department of Conservation and Land Management, Western Australia.

Wilkinson, L. 1989. SYSTAT: The System for Statistics. Evanston, IL: SYSTAT, Inc.

APPENDIX A1

APPENDIX A1. WARMS SPECIES by SITE DATA

33

[illegible]

34

[illegible]

APPENDIX A2

APPENDIX A2. ecologia ORD STAGE II DATA USED FOR COMPARISON WITH WARMS
SITES

Appendix A2: *ecologia* Ord Stage II data used for comparison with WARMS sites.

Species	KC2	KC6	KC13	KR2	KR13	KR16	WP1	WP6	WP11	WP12	IW1	IW13	CP47	CP48	CP54
* <i>Achyranthes aspera</i>	1													1	
* <i>Aerva javanica</i>												1			
†* <i>Calotropis procera</i> Cl. B (NT);		1													1
†* <i>Parkinsonia aculeata</i> Cl. B (NT);										1					
<i>Abelmoschus ficulneus</i>	1	1	1	1		1	1	1							
<i>Acacia bidwillii</i>		1		1		1	1								
<i>Acacia farnesiana</i>											1			1	
<i>Acacia hemignosta</i>							1								
<i>Aeschynomene indica</i>			1						1	1					
<i>Alloterospis semialata</i>										1					
<i>Ampelocissus acetosa</i>					1										
<i>Aristida holathera</i> var. <i>holathera</i>					1							1			
<i>Aristida latifolia</i>	1	1	1	1		1	1	1	1	1	1		1	1	
<i>Astrebla squarrosa</i>	1														
<i>Atalaya hemiglauc</i>	1	1	1	1		1									
† <i>Atalaya salicifolia</i> 3 r (NT)								1	1						
<i>Barringtonia acutangula</i>										1					
<i>Bonamia ?media</i>		1	1		1										
<i>Bonamia pannosa</i>												1			
<i>Bothriochloa b. subsp. bladhii</i>					1										
<i>Brachyachne convergens</i>	1	1	1	1	1	1	1		1					1	
<i>Capparis lasiantha</i>				1											
<i>Capparis spinosa</i> var. <i>nummularia</i>							1								
<i>Carissa lanceolata</i>									1		1			1	
<i>Chrysopogon fallax</i>	1	1	1	1		1	1	1	1		1	1	1	1	
† <i>Corchorus fascicularis</i> 3 r (N.T.)	1	1	1							1					
* <i>Corchorus olitorius</i>			1				1			1					1
<i>Corymbia bella</i>									1	1					
<i>Crotalaria juncea</i>							1								
<i>Cyanotis axillaris</i>															1
<i>Cyperus bifax</i>	1			1											1
<i>Cyperus conicus</i>										1					
<i>Cyperus</i> sp.			1			1			1						
<i>Dichanthium fecundum</i>				1				1			1		1		1
<i>Dichanthium sericeum</i>				1			1		1	1			1		1
<i>Dolichandrone heterophylla</i>					1		1								
<i>Ehretia saligna</i>	1			1				1	1						
† <i>Enteropogon minutus</i>									1						
<i>Eragrostis tenellula</i>			1	1				1	1	1					1
<i>Eriachne glauca</i>									1		1				
<i>Eriachne ?obtusa</i> (fine culms)											1				
<i>Erythrophleum chlorostachys</i>					1										
<i>Eucalyptus camaldulensis</i>												1			
† <i>Eucalyptus microtheca</i>	1		1		1										
<i>Eucalyptus pruinosa</i>											1				
<i>Eulalia aurea</i>										1					
† <i>Excoecaria parvifolia</i>	1					1			1						
<i>Ficus opposita</i>					1							1			1
<i>Flemingia pauciflora</i>	1	1		1		1	1	1							
<i>Gomphrena canescens</i>												1			
<i>Grewia retusifolia</i>							1		1						
<i>Heteropogon contortus</i>					1						1	1		1	
<i>Hibiscus panduriformis</i>		1		1	1	1	1			1					
<i>Indigofera trita</i>				1			1	1							
<i>Ischaemum australe</i>										1					
<i>Iseilema fragile</i>	1	1	1	1		1	1	1	1		1		1	1	1
<i>Leptochloa neesii</i>									1	1					
<i>Ludwigia perennis</i>									1						
<i>Lysiphyllum cunninghamii</i>	1	1	1	1		1	1	1	1		1			1	1
<i>Melia azedarach</i>															1
<i>Melochia pyramidata</i>		1				1				1					1
<i>Neptunia cf. dimorphantha</i>		1													1

* = Introduced Taxa; † = Flora of Interest

ecologia

Appendix A2: *ecologia* Ord Stage II data used for comparison with WARMS sites.

Species	KC2	KC6	KC13	KR2	KR13	KR16	WP1	WP6	WP11	WP12	IW1	IW13	CP47	CP48	CP54
<i>Neptunia major</i>											1				
<i>Neptunia monosperma</i>			1	1		1	1	1		1					1
<i>Ophiuros exaltatus</i>				1	1		1			1					
<i>Panicum decompositum</i>	1		1	1		1	1	1	1	1	1		1	1	1
<i>Panicum laevinode</i>						1			1						
<i>Phyllanthus maderaspatensis</i>			1				1	1			1				
<i>Polymeria</i> sp. A 'Kimberley'				1							1		1		1
<i>Pterocaulon serrulatum</i>											1	1			
<i>Ptilotus spicatus</i>	1	1	1					1							
<i>Rhynchosia minima</i>		1		1			1	1							
<i>Sauropus trachyspermus</i>										1					
<i>Sehima nervosum</i>				1			1								
<i>Senna planiticola</i>											1				
<i>Sesbania simpliciuscula</i>	1						1	1	1	1					
<i>Sida spinosa</i>	1	1	1	1		1	1	1	1	1					
<i>Sorghum timorense</i>				1		1	1	1		1					
<i>Stemodia tephropelina</i>			1		1										
<i>Streptoglossa bubakii</i>				1			1	1			1				
<i>Terminalia oblongata</i>				1											
<i>Themeda triandra</i>				1	1		1		1		1				
<i>Tinospora smilacina</i>												1			
<i>Trichodesma zeylanicum</i>		1		1		1		1							1
<i>Triumfetta ?grisella</i>												1			
<i>Urochloa reptans</i>				1			1								
<i>Ventilago viminea</i>			1												
<i>Waltheria indica</i>											1				

* = Introduced Taxa; † = Flora of Interest

ecologia

APPENDIX L
KEEP RIVER AQUATIC FAUNA SURVEY

MAGNT RESEARCH REPORT No. 4
FEBRUARY 1999

KEEP RIVER AQUATIC FAUNA SURVEY

HELEN LARSON



Museums and Art Galleries of the Northern Territory

MAGNT RESEARCH REPORT No. 4, FEBRUARY
1999

KEEP RIVER AQUATIC FAUNA SURVEY

REPORT TO KINHILL PTY LTD

HELEN LARSON

No part of this unpublished report may be reproduced without the written permission of the Director, Museums and Art Galleries of the Northern Territory.



The Museums and Art Galleries of the Northern Territory Research Report series is a medium for the dissemination of the results of research undertaken by MAGNT staff in the fields of Natural Sciences, History and Culture. All contributions are reviewed internally by staff of the MAGNT.

First printed 16 February, 1999

© 1999 Museums and Art Galleries of the Northern Territory. No part of this unpublished report may be reproduced or specifically cited without the written permission of the Director, Museums and Art Galleries of the Northern Territory.

CONTENTS

ACKNOWLEDGMENTS	4
INTRODUCTION.....	5
METHODS	6
COLLECTING SITES.....	7
FISH SPECIES	18
CRUSTACEA.....	24
MOLLUSCA.....	24
DISCUSSION	25
CONCLUSIONS	28
REFERENCES	31
APPENDIX I. Bird species.....	34
APPENDIX II. Amphibian, reptile and mammal species	37

ACKNOWLEDGMENTS

Invaluable assistance in the field was provided by Mr Paul Horner, who is also responsible for identification of many of the birds, and all of the frogs and reptiles, observed or collected at the sampling sites. Dr Richard Willan (MAGNT) identified the molluscs. Mr Rex Williams (MAGNT) provided technical help in the laboratory and prepared the locality map.

KEEP RIVER AQUATIC FAUNA SURVEY

REPORT TO KINHILL PTY LTD

HELEN LARSON

*Museum and Art Gallery of the Northern Territory
PO Box 4646, Darwin NT 0801, Australia*

INTRODUCTION

The fish fauna of the Northern Territory is not yet well known, and there are many gaps in our knowledge (Larson, in prep.; Larson and Williams 1997; Russell and Houston 1989). Northern Territory freshwater fishes and their distribution are better known than marine or estuarine fishes, mostly due to mining interests in the Alligator Rivers region (Larson and Martin 1990). For example, the coastal and freshwater fishes of Kakadu National Park, which includes most of this region, are therefore reasonably well known (Press *et al.* 1995; Larson 1997).

In contrast, the Keep River system is poorly known and its fishes (indeed, any of its aquatic fauna) have never been properly studied. The Keep forms part of the Timor Sea drainage system of the Northern Territory and drains an area of 12,300 km² (Midgley 1981). Only three brief *ad hoc* collections of fishes have been made in the Keep River: a three-day sampling of Policeman Waterhole in 1981 (Midgley 1981) and two by the Conservation Commission of the Northern Territory in 1975 and 1980 (based on specimens held at MAGNT). No survey of its estuarine fauna has ever been attempted (Larson in prep.).

A survey of the Keep River aquatic fauna, with emphasis on fishes, was requested by Kinhill, for the Ord River Irrigation Scheme Stage 2. The Stage 2 proposed development includes broadacre irrigation horticultural cropping within the catchment of the Keep River. Irrigation water would be sourced via a new (M2) open channel from the Kununurra Diversion Dam. Additional farm drains and stormwater drains would also enter the Keep. In addition, structural changes such as levees, a bridge and water regulating storage would be included in the development. The development, therefore, has potential for impacts on the Keep River drainage system and its associated biota.

The survey was carried out from 5-11 October, 1998, in the late dry season. The timing and brevity of the survey was constrained by external factors.

METHODS

Sampling was carried out by two people using multipanel gill-nets, fine-mesh seine, one-person scoop-nets, hook and line (casting rod), dip-net and torch at night, and sight observations. The possibility of Estuarine Crocodiles in the waterbodies prevented snorkeling and visual census methods being used. Sampling sites and methods used were constrained by site access and topology. Upon arrival at a particular locality, most sampling was done with scoop-nets, which resemble small one-person seine nets, for at least an hour (unless the site was plainly depauperate). The scoop-nets, based on a Japanese design, have two handles 1 m long, and multifilament nylon mesh (4 mm knot to knot). If the habitat was suitable, a small fine-mesh seine and gill-nets would be used. Scoop-nets are more efficient among aquatic vegetation than seines.

The two multi-panel gill-nets are each 35 m long, with a drop of 2 m, and seven 5 m long panels each of a different mesh size: 26, 44, 58, 76, 100, 126, and 150, knot to knot. The differing mesh sizes allows sampling of a wide range of fish species and sizes (e.g. from small rainbowfish to adult barramundi). Gillnets were normally set for one hour, to prevent drowning any Freshwater Crocodiles and killing too many fish. Wherever possible, these nets are set so that one is at a right angle to the bank, and one is parallel to the bank (to capture fishes travelling down the centre of the waterbody as well as those moving along the bank close to shelter). The nets are tied or anchored and buoyed so that they remain stationary, and left for approximately an hour in the afternoon, then re-set for another hour in the evening, with sunset occurring during the latter set, where possible.

At night, additional sampling with scoop-nets and small aquarium dip-nets was carried out at each locality. This enables observation and capture of nocturnally-active fish such as eel-tailed catfish, and ease of capture of other species (which may be sleeping).

The seine, scoop-net and dip-net sampling techniques also capture macroinvertebrates such as crustaceans, aquatic insects and molluscs. Terrestrial habitats adjoining watercourses were sampled opportunistically, by hand-collecting and spot-light, for reptiles and amphibians. A range of these organisms were retained for identification.

Specimens were brought back to the Museum and Art Gallery of the Northern Territory, Darwin (MAGNT), sorted and identified, identification confirmed, and deposited as vouchers in the MAGNT reference collection. Specimens deposited in the collection will be registered, and habitat and physical data included in the MAGNT database.

Localities were fixed using a Magellan hand-held GPS. Temperature, salinity and conductivity were recorded by a YSI model 30 system, while pH was recorded using a "Blue Water" test kit. Unfortunately, short notice for the field program prevented the use of a more sophisticated data logger, which was unavailable for the time period required.

On 9-10 October, the intense heat limited work during the day.

Due to circumstances beyond my control, it has not been possible to have the aquatic insects identified in time for inclusion in this report. A separate report on the insect fauna will be prepared.

COLLECTING SITES

The sites visited are listed below, including habitat and water quality descriptions (and see Fig. 2). Stations are numbered consecutively. Note that the first station is HL 98-35, not 98-1.

HL 98-35

Keep River National Park, “Bucket Spring” by northern park border, at small open pool (Fig. 2) in un-named creek fed by spring flowing from escarpment. 15° 44’ 47” S 129° 10’ 18” E. Water clear, 27.7°C, 0.2 ppt, 425.9 μ s, 1.5 m deep, current slow. Substrate rocks, sand, rubble, leaf litter and logs. Bright green sponges present on some limestone rocks (Spongillidae, probably *Radiospongilla* sp.). Aquatic vegetation of mixed grasses, reeds (*Eleocharis*), and taro (*Colocasia esculenta*) along edges. Shore steep sandy-clay banks, with few big *Melaleuca*, open woodland behind. 5 October 1998. 0830-1000 hrs. Coll. H. Larson, by scoop-net, hand.



Fig. 1. Pool of “Bucket Spring”, HL 98-35.

HL 98-36

Keep River National Park, “Bucket Spring” by northern park border, at larger open pool (Fig. 3) downstream from 98-35. 15° 45’ 00” S 129° 10’ 05” E. Water clear, 27.7°C, 0.2 ppt, 431 μ s, pH 7.6, 2.5-3 m deep, current slow. Substrate rock, loose rocks, leaf litter and logs. Aquatic vegetation of mixed grasses, reeds (*Eleocharis*), and taro (*Colocasia esculenta*) along edges. Shore steep sandy-clay banks, with large *Melaleuca*, open woodland behind. 5 October 1998. 1045-1130 hrs. Coll. H. Larson and P. Horner, by multipanel gill-net.

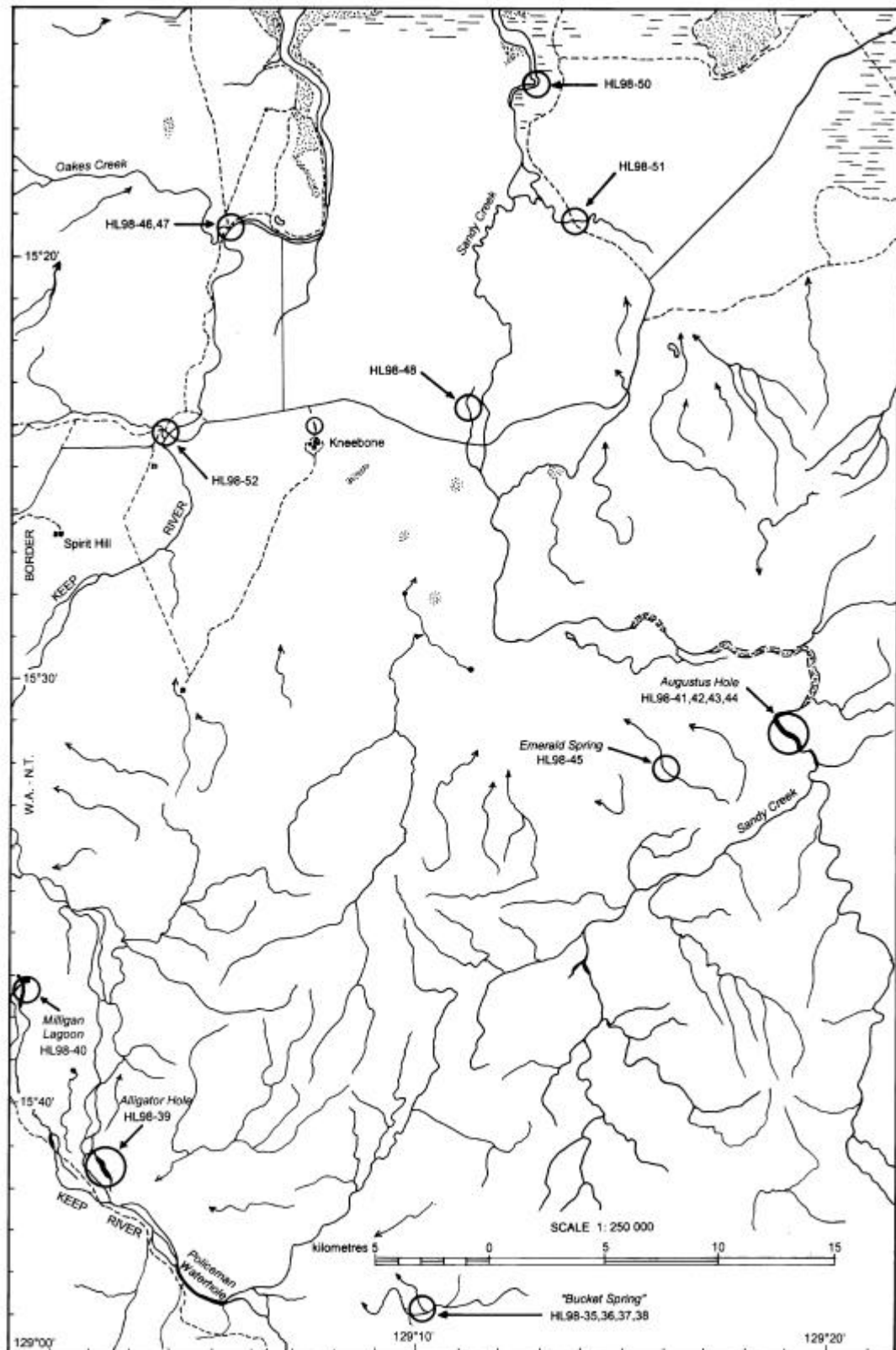


Fig. 2. Map of the Keep River and Sandy Creek area showing localities sampled (circled). Topography other than watercourses not indicated.



Fig. 3. “*Megalops*” pool at “Bucket Spring”, HL 98-36.

HL 98-37

Keep River National Park, “Bucket Spring” by northern park border, at very shallow pool (fig. 4) further downstream from 98-36; creek flowing through rush/grass thickets at either end of pool. 15° 44' 58" S 129° 09' 45" E. Water clear, 28.9°C, 433.9 μ s, pH 7.6, 0.25 m deep, current slow. Substrate sand, leaf litter. Aquatic vegetation reduced; *Marsilea* sp. in water, small amount of reeds (*Eleocharis*), grasses and taro (*Colocasia esculenta*) along edges. Shore sloping sandy-clay banks, with *Melaleuca*, *Barringtonia acutangula* and *Nauclea orientalis*, with open woodland behind. 5 October 1998. 1100-1200 and 2100-2215 hrs. Coll. H. Larson and P. Horner, by scoop-net and dip-nets.



Fig. 4. Shallow sandy pool, “Bucket Spring”, HL 98-37.

HL 98-38

Keep River National Park, “Bucket Spring” by northern park border, in deep open hole in “dry” arm of creek (Fig. 5) fed by slow trickle from spring, creek shallow, mostly rush-filled. 15° 44’ 59” S 129° 10’ 16” E. Water clear, 28.9°C, 475 μ s, pH 7.6, 1.5 m deep, current slight. Substrate sand, rocks, leaf litter. Aquatic vegetation of mixed grasses and taro (*Colocasia esculenta*) along edges. Shore low grassy banks and low *Melaleuca*, open woodland and escarpment behind. 5 October 1998. 1530-1700 hrs. Coll. H. Larson and P. Horner, by multipanel gill-net.



Fig. 5. Multipanel gill-net in “dry” arm of “Bucket Spring”, HL 98-38.



Fig. 6. North end of Alligator Hole, looking south; HL 98-39.

HL 98-39

Keep River drainage, Alligator Hole, a long deep steep-banked isolated billabong of the Keep River, rocky and muddy at north end (Fig. 6), sandy with mud at south end, about 25 m wide. 15° 41' 20" S 129° 02' 13" E. Water somewhat turbid olive colour, 30.6°C, 0 ppt, 82.2 µs, pH 6.8, 2.7 m deep in centre, no current. Substrate sand, mud, rocks, leaf litter and logs. Aquatic vegetation of *Nymphaea* sp. (*N. macrosperma* or *N. violacea*), *Nymphoides* sp. (probably *N. indica*, none flowering), and *Urtricularia australis*. Shore steep sandy banks, with varied riparian vegetation, open woodland behind. 6 October 1998. 1400-1615 and 1830-2100 hrs. Coll. H. Larson and P. Horner, using two multipanel gill-nets.

HL 98-40

Keep River drainage, Milligan Lagoon (Fig. 7), a large open curved isolated billabong of the Keep River, in blacksoil plains. 15° 37' 17" S 129° 00' 20" E. Water somewhat turbid yellow-grey colour, 31.1°C, 0 ppt, 82.1 µs, pH 7.2, about 1.5 m deep, no current. Substrate thick deep mud, leaf litter. Aquatic vegetation of *Nymphaea* (*N. macrosperma* or *N. violacea*), *Hydrilla verticillata* and *Chara* sp., forming dense mats. Bright green spiky sponge on vegetation (Spongillidae, probably *Radiospongilla* sp.). Shore open sloping blacksoil banks, with short grasses, *Barringtonia acutangula* and *Lysiphyllum cunninghamii*, open woodland behind. 7 October 1998. 1130-1230 hrs. Coll. H. Larson, by scoop-net.



Fig. 7. Milligan Lagoon, north end, HL 98-40.

HL 98-41

Sandy Creek, Augustus Hole, a large waterhole in main creek bed (Fig. 8). 15° 31' 31" S 129° 19' 11" E. Water clear, 32.7°C, 0.1 ppt, 311.9 µs, pH 7.6, 1.5 m deep, no current. Substrate coarse sand, leaf litter. Aquatic vegetation absent. Shore on east bank a rocky gorge, on west bank steep sandy banks, with riparian vegetation mostly of *Pandanus spiralis*, *Melaleuca*, *Barringtonia acutangula* and *Nauclea orientalis*, open woodland behind. 7 October 1998. 1700-1900 and 2030-2130 hrs. Coll. H. Larson and P. Horner, by scoop-net and hook and line.



Fig. 8. Sandy beach near south end of Augustus Hole, HL 98-41.

HL 98-42

Sandy Creek, Augustus Hole, at south end of main waterhole where it meets small spring-fed creek flowing over small boulders (Fig. 9), among grassy banks. 15° 31' 42" S 129° 19' 30" E. Water clear, 30.8°C, 0.2 ppt, 312.2 μ s, pH 7.6, 0.5-1.5 m deep, current slow to moderate. Substrate rocks, sand, small boulders, *Melaleuca* leaf litter. Some green ?*Radiospongilla* sp. and algae present on rocks. Aquatic vegetation practically absent, some small *Eleocharis* sp. and grasses. Shore open, almost no banks, with grasses, few *Pandanus spiralis* and *Melaleuca* sp., open woodland behind. 8 October 1998. 0930-1030 hrs. Coll. H. Larson, by scoop-net.



Fig. 9. South end Augustus Hole, HL 98-42.

HL 98-43

Sandy Creek, Augustus Hole, at north end of main waterhole (Fig. 10), forming series of small open sandy and rocky pools joined by narrow stream. 15° 31' 00" S 129° 18' 46" E. Water clear, 30.9°C, 0.2 ppt, 333.2 μ s, pH 7.6, 0.5 m deep, current slow to moderate. Substrate

white sand, rocks, leaf litter. Aquatic vegetation practically absent, some small *Eleocharis* sp. Shore low grassy banks, with grasses, overhanging *Pandanus spiralis* and *Melaleuca* sp., open woodland behind. 8 October 1998. 1115-1145 hrs. Coll. H. Larson, by scoop-net.



Fig. 10. Open rocky pool, north end Augustus Hole, HL 98-43.

HL 98-44

Sandy Creek, Augustus Hole, just north of sandy beach by campsite near south end of waterhole. 15° 31' 31" S 129° 19' 11" E. Water clear, 32.7°C, 0.1 ppt, 311.9 µs, pH 7.6, 2-2.7 m deep, no current. Substrate coarse sand, leaf litter. Aquatic vegetation absent. Shore on east bank a rocky gorge, on west bank steep sandy banks, with riparian vegetation mostly of *Pandanus spiralis*, *Melaleuca*, *Barringtonia acutangula* and *Nauclea orientalis*, open woodland behind. 8 October 1998. 1230-1340 hrs. Coll. H. Larson and P. Horner, two multipanel gill-nets.

HL 98-45

Sandy Creek drainage, Emerald Spring (Fig. 11), large spring-fed (?) pool at base of vertical sandstone cliff. 15° 31' 59" S 129° 15' 55" E. Water greenish, relatively clear, 32°C, 0 ppt, 20.8 µs, pH 6.4, about 2.5 m deep, no current. Substrate sand, rock, leaf litter. Aquatic vegetation green algae on rocks and plant rootlets. Shore half sandstone cliff, half sloping sandy banks bound by rootlets, few *Melaleuca*, with open woodland behind. 8 October 1998. 1600-1700 and 2045-2130 hrs. Coll. H. Larson, by scoop-net.



Fig. 11. Cliff and pool, Emerald Spring, HL 98-45.



Fig. 12. Oakes Creek by junction with Keep River, HL 98-46.

HL 98-46

Keep River system, Oakes Creek, at junction with Keep River (Fig. 12), creek broken into series of shallow pools. 15° 19' 19" S 129° 05' 21" E. Water turbid, 35.1°C, 48.8 ppt, 0.5 m deep, no current. Substrate sand, rock, mud layer mixed with sand. Aquatic vegetation absent, green algal bloom in some pools. Last pool in which fish were found, about 0.5 km up creek from junction, was 40.5°C, 42.5 ppt. Shore low sandy banks of low grasses and small bushy *Melaleuca* sp., low open savannah woodland behind. 9 October 1998. 1430-1515 hrs. Coll. H. Larson, by scoop-net.

HL 98-47

Keep River, in river directly opposite junction with Oakes Creek (Fig. 13). 15° 19' 21" S 129° 05' 24" E. Water somewhat turbid, 33.3°C, 47 ppt, 2 m deep, current slow. Almost no tidal movement. Substrate mud, sandy mud, rock, logs. Aquatic vegetation absent. Shore low muddy banks with scattered low grasses, *Sesuvium portulacastrum*, *Aegiceras corniculatum*, *Avicennia marina*, small bushy *Melaleuca* sp., low open savannah woodland behind. 9 October 1998. 1730-1900 and 2000-2200 hrs. Coll. H. Larson and P. Horner, by two multipanel gill-nets.



Fig. 13. Keep River, by junction with Oakes Creek, HL 98-47.

HL 98-48

Sandy Creek, billabongs in broad rounded sandy un-named creek bed (Fig. 14) broken into series of pools 0.25-1 km long. 15° 23' 38" S 129° 11' 10" E. Water clear greenish, 32.8°C, 0.1 ppt, 99.5 µs, pH 7.2, 1.5 m deep, no current. Substrate sand, leaf litter, thick vegetation, logs and sticks. Aquatic vegetation *Chara* sp., *Urticularia australis*, *Najas tenuifolia*, *Nymphaea* (*N. macrosperma* or *N. violacea*); *Enteromorpha* sp. and other green algae forming blooms at ends of some pools. Shore low to steeply sloping sandy banks, grassy, with scattered *Eucalyptus* and *Melaleuca*, open woodland behind. 10 October 1998. 1530-1700-2000-2100 hrs. Coll. H. Larson and P. Horner, by 20' seine and scoop-nets.



Fig. 14. Sandy Creek billabong, one of several; HL 98-48.

HL 98-49

Sandy Creek estuary, east bank (Fig. 15). 15° 16' 05" S 129° 12' 55" E. Water muddy grey-green, 30.1°C, 40.5 ppt, 2 m deep, current slow. Tide low. Substrate mud. Aquatic vegetation absent. Shore on east bank steep mud banks, grass-topped, with wide salt flat behind, on which were scattered grasses (*Sporobolus virginicus*), *Sesuvium portulacastrum* and small bushy *Melaleuca* sp. 11 October 1998. 1110 hrs. Sight record only, H. Larson.



Fig. 15. Sandy Creek estuary, looking upstream, HL 98-49.

HL 98-50

Sandy Creek estuary, isolated pool in small creeklet entering estuary on east bank (Fig. 16), just inland from HL 98-49. 15° 16' 05" S 129° 12' 55" E. Water turbid, muddy, 34.6°C, 45.3 ppt, 0.5 m deep, no current. Substrate mud. Aquatic vegetation absent. Shore salt flat, with *Sesuvium portulacastrum*. 11 October 1998. 1115-1145 hrs. Coll. H. Larson, by scoop-net.



Fig. 16. Salt flats, Sandy Creek estuary, just east of HL 98-50.

HL 98-51

Sandy Creek tributary, isolated pool in narrow eroded channel (Fig. 17), one of several, rest of channel dry. 15° 19' 11" S 129° 13' 51" E. Water rather turbid greenish, 39°C, 61.1 ppt, 0.5-1 m deep, no current. Substrate clay, mud, logs, many fallen trees. Aquatic vegetation absent. Shore steep clay-mud banks full of tree roots, with low open woodland behind, mostly *Melaleuca*. 11 October 1998. 1245-1300 hrs. Coll. H. Larson, by scoop-net.



Fig. 17. Tributary channel of Sandy Creek, HL 98-51.

HL 98-52

Keep River, on south side of bridge where Legune Station road crosses river (Fig. 18), river broken into series of large pools. 15° 24' 23" S 129° 03' 45" E. Water somewhat turbid, greenish, 32.5°C, 0.1 ppt, 163.1 µs, pH 7.2, at least 1 m deep, no current. Substrate rock slabs, rocks, gravel, sand, logs and leaf litter. Aquatic vegetation absent. Shore steep blacksoil banks with *Pandanus ?aquaticus*, *Barringtonia acutangula* and *Melaleuca* sp., open woodland behind. 11 October 1998. 1415-1515 hrs. Coll. H. Larson and P. Horner, by scoop-net and hook and line.



Fig. 18. Keep River, just west of Legune Station road crossing, HL 98-52.

FISH SPECIES

The species listed here are based on the survey collections and sight records or literature records. Station numbers are given at which each species was collected, followed by number of specimens collected and their size range (in standard length) in parentheses. All specimens retained are registered in the NTM reference collection.

PRISTIDAE - SAWFISH

***Pristis clavata* Garman, 1906 – Dwarf Sawfish**

Pristis clavata Garman, 1906: 208 (Queensland, Australia).

HL 98-47, 1(840).

This small species is definitely known only from northern Australia so far, from Cairns to the Kimberley coast. It is usually found in estuaries or close to the coast.

***Pristis microdon* Latham, 1794 – Freshwater Sawfish**

Pristis microdon Latham, 1794: 280 (no locality). - Midgley 1981: 56 (Police Hole).

No material was retained from Midgley's collection, but his identification is accepted here, given that this isolated site is well up into freshwater (the preferred habitat of this species). It is possible that Midgley's specimen was also *P. clavata*, as the two species have been confused in the past (P. Last, pers. comm.). *Pristis microdon* is known from the Victoria, Daly and Adelaide Rivers (and elsewhere in northern Australia and South-east Asia) and appears to be confined mostly to fresh water (Last and Stevens 1994).

MEGALOPIDAE - TARPONS

***Megalops cyprinoides* (Broussonet, 1782) – Ox-eye Herring**

Clupea cyprinoides Broussonet, 1782: 39 (Tanna, New Hebrides)

HL 98-36, 1(388); HL 98-38, 1(discarded); HL 98-39, 3(189-201); HL 98-45, sight record only; HL 98-48, sight record only.

CLUPEIDAE - HERRINGS

***Nematalosa erebi* (Günther, 1868) – Bony Bream**

Chatoessus erebi Günther, 1868: 407 (Mary River, Queensland).

Nematalosa erebi - Midgley 1981: 56 (Police Hole).

HL 98-39, 10(77-172); HL 98-42, sight record only; HL 98-44, released; HL 98-47, 1(207). Also specimens in NTM collection from Policeman Waterhole and Cockatoo Lagoon.

ENGRAULIDIDAE - ANCHOVIES

***Thryssa brevicauda* Roberts, 1978 – Short-tail Thryssa**

Thryssa brevicauda Roberts 1978: 29 (mangrove creek, Lower Fly River, PNG).

HL 98-47, 4(90-101).

ARIIDAE - FORK-TAILED CATFISH

***Arius graeffei* Kner and Steindachner, 1866 – Blue Catfish**

Arius graeffei Kner and Steindachner, 1866: 383 (Samoa, locality doubtful).

HL 98-39, 11(155-173); HL 98-44, 1(243); HL 98-47, 3(180-310). Also specimens in NTM collection from Policeman Waterhole.

***Arius leptaspis* (Bleeker, 1862) – Salmon Catfish**

Hexanematicthys leptaspis Bleeker, 1862: 27 (New Guinea).

NTM S.11405-008, from Policeman Waterhole. The "ariid sp." reported by Midgley (1981) from "Police Hole" could be this species or *Arius graeffei* (specimens not retained).

***Arius midgleyi* Kailola and Pierce, 1866 – Midgley’s Catfish**

Arius midgleyi Kailola and Pierce, 1988: 75-87 (Wickham Gorge, Victoria River, Northern Territory).

HL 98-44, large specimen, released.

PLOTOSIDAE - EEL-TAILED CATFISH

***Anodontiglanis dahli* Rendahl, 1922 – Toothless Catfish**

Anodontiglanis dahli Rendahl, 1922: 169 (Glencoe River, Glencoe, NT).

HL 98-44, 1(318-320), larger specimen skeletonised.

***Neosilurus ater* (Perugia, 1894) – Black Catfish**

Lambertia atra Perugia, 1894: 551 (Inawi, New Guinea).

Specimens in NTM collection from Policeman Waterhole.

***Neosilurus hyrtlii* (Steindachner, 1867) – Hyrtl’s Catfish**

Neosilurus hyrtlii Steindachner, 1867: 14 (Fitzroy River, Rockhampton).

HL 98-35, sight record only; HL 98-45, 3(105-120).

***Porochilus rendahli* (Whitley, 1928) – Rendahl’s Catfish**

Copidoglanis rendahli Whitley, 1928: 214 (substitute name for *Copidoglanis obscurus* Rendahl, preoccupied).

HL 98-37, possible sight record only. Specimens in NTM collection from Policeman Waterhole.

BELONIDAE - LONGTOMS

***Strongylura krefftii* (Günther, 1866) – Freshwater Longtom**

Belone krefftii Günther, 1866: 250 (Australia).

HL 98-44, 2(347-560), larger skeletonised.

MELANOTAENIIDAE - RAINBOWFISH

***Melanotaenia nigrans* (Richardson, 1843) – Black-banded Rainbowfish**

Atherina nigrans Richardson, 1843: 180 (King River, Port Essington, NT).

HL 98-45, 17(13-75).

***Melanotaenia splendida australis* (Castelnau, 1875) – Red-tailed Rainbowfish**

Neoatherina australis Castelnau, 1875: 32 (Swan River Colony, WA).

Melatontaenia sp. - Midgley 1981: 56 (Police Hole).

HL 98-35, 10(13-47); HL 98-36, sight record only; HL 98-37, 18(15-55); HL 98-39, 23(15-33); HL 98-41, 33(9-30); HL 98-42, 9(8-40); HL 98-43, 2(29-30); HL 98-45, 23(18-70); HL

98-48, 35(11-50); HL 98-52, 28(7-19). Specimens in NTM collection from Cockatoo Lagoon and West Gorge, Keep River.

ATHERINIDAE - HARDYHEADS

***Craterocephalus stercusmuscarum* (Günther, 1867) – Fly-specked Hardyhead**

Atherina stercusmuscarum Günther, 1867: 64 (Cape York).

HL 98-35, 2(17-18); HL 98-36, sight record only; HL 98-39, 14(22-53); HL 98-40, 35(11-30); HL 98-41, 30(12-47); HL 98-42, 1(22); HL 98-43, 5(14-20).

AMBASSIDAE - GLASS-PERCHLETS

***Ambassis mulleri* Klunzinger, 1879 – Muller's Glassfish**

Ambassis mulleri Klunzinger, 1879: 346 (Port Darwin).

HL 98-37, 4(33-35); HL 98-39, 2(21-23); HL 98-41, 2(12-21); HL 98-45, 1(31); HL 98-48, 77(27-42). Also specimens in NTM collection from the Keep River and Cockatoo Lagoon.

***Parambassis gulliveri* (Castelnau, 1878) – Giant Glassfish**

Acanthopercra gulliveri Castelnau, 1878: 45 (Norman River, Gulf of Carpentaria).

HL 98-39, 4(103-120). Specimens in NTM collection from a Keep River billabong.

CENTROPOMIDAE - BARRAMUNDI

***Lates calcarifer* (Bloch, 1790) - Barramundi**

Holocentrus calcarifer Bloch, 1790: 100 (Japan).

Lates calcarifer - Midgley 1981: 56 (Police Hole).

HL 98-41, 1(270); HL 98-42, sight record only; HL 98-44, sight record only; HL 98-48, released; HL 98-52, sight record only.

TERAPONTIDAE - GRUNTERS

***Amniataba percoides* (Günther, 1864) – Banded Grunter**

Therapon percoides Günther, 1864: 374 (Fitzroy River, near Rockhampton).

Amniataba percoides - Midgley 1981: 56 (Police Hole).

HL 98-41, 18(8-23); HL 98-42, 2(11-11). Specimens in NTM collection from Policeman Waterhole.

***Hephaestus jenkinsi* (Whitley, 1945) – Jenkins' Grunter**

Mesopristes jenkinsi Whitley, 1945: 26 (Ivanhoe Station, Ord River, WA).

HL 98-41, 1(255).

***Leiopotherapon unicolor* (Günther, 1859) – Spangled Grunter**

Therapon unicolor Günther, 1859: 277 (Gwydir River and Darling Downs, NSW).

Leiopotherapon unicolor - Midgley 1981: 56 (Police Hole).

HL 98-35, sight record only; HL 98-36, sight record only; HL 98-37, 1(67); HL 98-42, sight record only; HL 98-45, sight record only. Specimens in NTM collection from Policeman Waterhole, Cockatoo Lagoon and West Gorge, Keep River.

***Terapon jarbua* (Forsskal, 1775) - Targetfish**

Sciaena jarbua Forsskal, 1775: 12 (Djeddah, Red Sea.).

HL 98-46, 8(9-13); HL 98-50, 13(11-22); HL 98-51, 3(15-19).

APOGONIDAE - CARDINALFISH

***Glossamia aprion* (Richardson, 1842) – Mouth Almighty**

Apogon aprion Richardson, 1842: 16 (King River, Victoria, Port Essington, NT).

HL 98-37, 1(67); HL 98-39, 1(48); HL 98-40, 13(11-21); HL 98-41, 5(21-32); HL 98-42, 1(62); HL 98-45, 6(10-132); HL 98-48, 6(20-51).

TOXOTIDAE - ARCHERFISH

***Toxotes chatareus* (Hamilton Buchanan, 1822) – Spotted Archerfish**

Coius chatareus Hamilton Buchanan, 1822: 101, 370 (mouths of the Ganges).

Toxotes chatareus - Midgley 1981: 56 (Police Hole).

HL 98-39, 2(122-125); HL 98-41, 1(177); HL 98-47, sight record only; HL 98-52, sight record only. Specimens in NTM collection from Policeman Waterhole.

MUGILIDAE - MULLET

***Liza cf alata* (Steindachner, 1892) – Diamond Mullet**

Mugil alata Steindachner, 1892: 133 (Madagascar).

HL 98-50, 44(6-45).

These juvenile specimens appear to belong to this species, however, juvenile mugilids are notoriously difficult to identify.

***Liza tade* (Forsskal, 1775) – Flathead Mullet**

Mugil crenilabis var. *tade* Forsskal, 1775: 74 (Red Sea).

HL 98-98-47, 6(180-320).

This species usually has bright orange to red markings on the eye; however, these specimens varied from orange to bright green. Only one specimen had orange-red eye markings and bright yellow on the fins (resembling specimens taken from mangrove creeks on Field Island, Kakadu National Park).

***Rhinomugil nasutus* (De Vis, 1883) – Pop-eye Mullet**

Mugil nasutus De Vis, 1883: 621 (Cardwell, Qld).

HL 98-50, 1(39).

POLYNEMIDAE - THREADFINS

***Eleutheronema tetradactylum* (Shaw, 1804) – Four-finger Threadfin**

Polynemus tetradactylus Shaw, 1804: 155 (India).

HL 98-47, 1(255)

ELEOTRIDIDAE - GUDGEONS

***Mogurnda mogurnda* (Richardson, 1844) – Purple-spotted Gudgeon**

Eleotris mogurnda Richardson, 1844: 4 (Port Essington).

HL 98-35, sight record only; HL 98-37, 16(13-76). Specimens in NTM collection from Keep River and Cockatoo Lagoon.

***Oxyeleotris selheimi* (Macleay, 1884) – Black-banded Gudgeon**

Eleotris selheimi Macleay, 1884: 33 (replacement name for *Eleotris planiceps* Macleay, 1882).

HL 98-39, 13(10-56); HL 98-40, 13(11-21); HL 98-48, 14(31-62). Specimens in NTM collection from Cockatoo Lagoon.

GOBIIDAE, GOBIINAE - GOBIES

***Amoya* sp. – Amoy Goby**

HL 98-50, 32(7-10).

This is a previously known undescribed species

***Glossogobius aureus* (Akihito and Meguro, 1975) – Golden Goby**

Glossogobius aureus Akihito and Meguro, 1975: 128 (Sumiyoshi, Iriomotejima, Okinawa Prefecture, Japan).

Glossogobius sp. - Midgley 1981: 56 (Police Hole).

HL 98-41, 17(17-50); HL 98-48, 14(14-76). Specimens in NTM collection from Policeman Waterhole.

GOBIIDAE, OXUDERCINAE - MUDSKIPPERS

***Oxuderces wirzi* (Koumans, 1938) – Peacock Mudskipper**

Apocryptodon wirzi Koumans, 1938: 26 (Papua New Guinea).

HL 98-50, 5(15-25).

***Periophthalmus argentilineatus* Valenciennes, 1837 – Silver-lined Mudskipper**

Periophthalmus argentilineatus Valenciennes, 1837: 191 (Irian Jaya and Moluccas).

HL 98-47, sight record only; HL 98-49, sight record, probably of this species.

CRUSTACEA

DECAPODA, PALAEMONIDAE

***Macrobrachium rosenbergii* (de Man, 1879)**

HL 98-52. *Macrobrachium rosenbergii* is a “Large, euryhaline, catadromous species ...”, found from the Fitzroy River in Western Australia across the Top End to the Normanby River in Queensland (Short, in prep.). Long-armed prawns (or cherabin) are sought after as food.

***Macrobrachium bullatum* Fincham, 1989**

HL 98-35. This is a small, oligohaline species restricted to north-western Australia, from the Lennard River in Western Australia to Rosie River, Northern Territory (Short, in prep.).

DECAPODA, ATYIDAE

***Caridinides wilkinsi* Calman, 1926.**

HL 98-35. This is a poorly known species, found in freshwaters of the Northern Territory and Queensland (Smith and Williams 1982). Coombes (1996) stated that the species is common in Top End freshwaters (from the Finnis system across to the Goyder), based on MAGNT records.

DECAPODA, OCYPODIDAE

***Uca* sp.**

HL 98-50. One specimen was collected, but was lost before identification could be made. There are 14 species of fiddler crabs known from the Northern Territory (George and Jones 1982).

MOLLUSCA

GASTROPODA, PROSOBRANCHIA, VIVIPARIDAE

***Notopala essingtonensis* (Frauenfeld, 1862)**

HL 98-39; HL 98-40; HL 98-48.

Distribution: north coastal, Gulf of Carpentaria.

GASTROPODA, PULMONATA, LYMNAEIDAE

***Austropeplea lessoni* (Deshayes, 1830)**

HL 98-35; HL 98-37; HL 98-39; HL 98-40; HL 98-43.

Distribution: Coastal SE and NE Australia, Gulf of Carpentaria, W Plateau, southern gulfs, Murray-Darling basin, Bulloo River basin, Lake Eyre basin.

GASTROPODA, PULMONATA, PLANORBIDAE

***Amerianna carinata* (H. Adams, 1861)**

HL 98-40; HL 98-41.

Distribution: throughout coastal northern Australia; also introduced into Java, Thailand, Nigeria and Martinique.

***Gyraulus cf essingtonensis* (E.A. Smith, 1882)**

HL 98-48.

Distribution unknown, due to taxonomic uncertainty.

BIVALVIA, PALAEOHETERODONTA, HYRIIDAE

***Velesunio angasi* (Sowerby, 1867)**

HL 98-37; HL 98-40.

Distribution: Coastal Gulf of Carpentaria to Daly River catchment, Fitzroy River catchment, WA. Keep River specimens therefore represent a new locality record.

DISCUSSION

Over the seven-day survey period, 17 sampling stations were made, recording 32 freshwater and estuarine fish species (and 11 frogs, 13 reptiles, 93 birds, 5 mammals) from the Keep River and Sandy Creek region. Adding in the few additional species from the literature and museum collections, gives a total of 35 species of fishes known so far from the area. Of these 35, several are noteworthy.

Fishes - threatened species

The two species of sawfish found in the Keep River, the Dwarf Sawfish *Pristis clavata* and the Freshwater Sawfish *Pristis microdon*, are of national and international significance. These large elasmobranchs are poorly understood in Australia, and very little is known of their distribution and ecology.

Freshwater Sawfish, which grow to at least 2 metres in length, are “highly vulnerable” in waterbodies where barramundi gill net fishing is carried out, and may be threatened in areas where gill net poaching occurs (Last and Stevens 1994). The Freshwater Sawfish is listed as “Endangered” in the IUCN’s Red List, and as “Potentially Threatened” in the 1998 Australian Society for Fish Biology’s (ASFB) Threatened Fish List (ASFB’s Threatened Fish Committee is in the process of adopting IUCN methodology for determining the conservation status of fish species). In Australia, the Freshwater Sawfish is found in freshwater and upper reaches of estuaries, and may be isolated in small billabongs for several years, awaiting floods. This species

is known from several rivers in northern W.A., the N.T. and Cape York, Qld, but its true distribution is not known. The species is known from the Keep River only from Midgley's (1981) field report (no specimen retained).

The Dwarf Sawfish is usually coastal in distribution, but can travel long distances up rivers into freshwater. Mature males are not known from museum collections (the specimen obtained is a young male, awaiting further study). Its conservation status is not known (through lack of data), and it may only occur in northern Australia. The single specimen obtained during the survey was living in 47 ppt salinity, in the upper reaches of the Keep estuary.

Although both these species of sawfish do occur in other drainage systems in northern Australia, it should be borne in mind that the fish fauna of the Keep River system is practically pristine, with a very low level of fishing effort by commercial fishers due to its remoteness (e.g. no effort in the area in 1996 or 1997, Roland Griffin, DPIF, pers. comm.) and probably with a similarly low recreational fishing pressure. Other river systems have or may have had greater fishery pressure and therefore a potential impact on sawfish populations (and poaching is an unknown factor). Therefore the sawfish populations (and those of other fish species) may be intact in the Keep.

Fishes - freshwater species

The Black-lined Rainbowfish *Melanotaenia nigrans* was found only at one locality, Emerald Spring. This species occurs in many habitat types and has a wide but patchy distribution (Larson and Martin 1990). It is often most abundant in rocky or escarpment habitat and is usually found about 40 km from the coast (as is Emerald Spring).

The other freshwater fish species were those normally to be expected in the available habitats surveyed. The number of species recorded (25) is probably not complete. Hutchins (1981) and Allen (1982) recorded freshwater fishes from the Ord River or Lake Argyle, including several species expected from the Keep but not yet collected (such as Reticulated Glassfish *Ambassis macleayi*, Nurseryfish *Kurtus gulliveri*, Strawman *Craterocephalus stramineus*, and Butler's Grunter *Syncomistes butleri*). It is very likely that these species occur in the Keep and Sandy area, as they are also present in rivers to the east and west of these systems.

In the Northern Territory, the nearest river east of the Keep which has been surveyed more than once is the Wickham River, in the Victoria River drainage system. Thirty-five species are now known from the Wickham, of which 22 are shared with the Keep (Larson in prep.). In a six-day survey of the upper Wickham River, 20 of the 35 species were obtained with the same techniques used for the present survey.

In comparison, although about 44 "freshwater" species are known from the Alligator Rivers Region, only 25 of these were taken during sampling of the Nourlangie and Magela Creeks during a nine-day survey using the same techniques used for the present survey (Larson 1995). Twenty-five of the 35 species collected from the Keep and Sandy are generally considered to be "freshwater fishes" *sensu* Larson and Martin (1990). The basic species assemblages found in the Sandy and Keep systems are similar to those of the Alligator Rivers region but for groups which do not occur in the Victoria River system or westward of it, such as the Osteoglossidae (saratoga) and the freshwater species of the family Pseudomugilidae (blue-eyes).

There are no feral (introduced) fishes in these rivers. One possible invading species may be *Gambusia affinis*, the Mosquitofish, which has invaded many Western Australian river systems and is known from streams north of Broome and may be colonising other streams (MAGNT records; Arthington and Lloyd 1989). The Mosquitofish was introduced in Darwin and some rivers between Darwin and the Fitzmaurice River in the 1940s, but the only known population remaining in the NT is in Railway Dam in the city of Darwin (Graham White, DPIF, pers. comm.).

Fishes - estuarine species

Ten of the 35 species recorded are estuarine species (e.g. Dwarf Sawfish *Pristis clavata*, Pop-eye Mullet *Rhinomugil nasutus*, Silver-lined Mudskipper *Periophthalmus argentilineatus*). By way of contrast, 181 fish species are known from the estuaries and coasts within Kakadu National Park (Larson 1997) and 107 from the Roper River estuary and nearby creeks (Larson 1996). The Keep River and Sandy Creek estuaries would be expected to have 100 or more species of estuarine fishes. The estuarine species recorded were obtained at two sites only (HL 98-47 on the Keep River and HL 98-50 on Sandy Creek). From the appearance of the habitat (rocky bars and muddy shoals with mangrove-lined banks) and considerable fish activity observed toward dusk and at night, there were many more species present than were recorded. To sample the estuarine habitats adequately, additional techniques are required (2 m beam trawl, rotenone) in addition to gill and scoop nets, using a larger vessel than the 10' aluminium dinghy used for this survey.

From observations made during the survey, it is expected that the estuarine fish fauna of the Keep and Sandy would likely be similar to that of the Roper River estuary and probably the Alligator Rivers estuaries. Additionally, Wells (1995) shows similarities, by presence/absence of mangrove species, between the rivers entering the Joseph Bonaparte Gulf (e.g. the Keep and Victoria) and those Northern Territory rivers entering the Gulf of Carpentaria (e.g. the Roper). These are all seasonally arid areas, with low mangrove diversity (Wells 1995). It has not yet been demonstrated if there is any link between low mangrove diversity and low diversity of fishes associated with the mangroves. There is a relationship between mangrove productivity (based on invertebrate diversity) and latitude (rainfall) indicated by Hanley and Banks (1995).

It is likely that the most speciose fish families in the Keep and Sandy estuaries will be the Gobiidae (gobies, gudgeons and mudskippers), Ariidae (fork-tailed catfish), Engraulidae (anchovies), Sciaenidae (jewfish), Mugilidae (mullet), Cynoglossidae (tongue soles), and the Clupeidae (sardines and herrings), although not necessarily in that order. However, the Gobiidae can be easily predicted to be the most speciose family, as it has been shown to be so in a number of coastal and estuarine habitats in the N.T. (Larson 1997; Larson and Williams 1997). The Gobiidae is also the most speciose marine fish family in the world (Nelson 1976).

Other vertebrates

Terrestrial vertebrates were observed or sampled on an *ad hoc* basis. Aquatic vertebrates other than fish were not sought (i.e. no traps deployed), so no turtles or watersnakes were recorded. Freshwater Crocodiles *Crocodylus johnstoni* were attracted to the gill nets and several became entangled (and were released unharmed). Midgley (1981) recorded a single Estuarine Crocodile, *Crocodylus porosus*, at Policeman Waterhole in Keep River National Park.

One species of note is the recently described scincid lizard *Ctenotus rimicola*, which has a subspecies (*Ctenotus rimicola camptris*) restricted to the black soil plains around the Keep River (Horner and Fisher 1998). Horner and Fisher rate the species' conservation status as "Rare or insufficiently known".

Aquatic invertebrates

The aquatic invertebrates comprised species assemblages usually associated with Northern Territory rivers, creeks and billabongs. Insects and molluscs were common in most waterbodies, and some insects locally abundant. The freshwater mussel *Velesunio angasi*, apparently abundant in the area, forms a new locality record for the species. Crustacea other than two species of *Macrobrachium* were not abundant. However, the abundance of atyid shrimps can be sporadic (Coombes 1996), so the more speciose atyid genus *Caridina* may be present in the region.

CONCLUSIONS

Much work has been done on terrestrial systems and groundwater hydrology but very little done on the biological systems that actually live **in** water. The Ord River Stage 2 development has the potential to impact the Keep River system and its associated aquatic biota considerably, adding water and its associated organisms from the Ord River system. The project, still under development, may include:

- the potential for irrigation water to enter the Keep, causing the river to flow continuously;
- hillside drains from Knox Creek Plain to enter the Keep River;
- a regulating storage dam of 3.5 gegaliters is proposed for the Keep River Plain;
- stormwater drains to enter the Keep River, via natural drainage systems, at several locations;
- flood protection levees, with their banks above the present surface, are presently proposed along the Keep River and Sandy Creek, with parts of the Keep possibly having levees built on both sides of the river;
- a bridge may be constructed across the Keep in the vicinity of the existing Legune Station road;
- approximately 540 km of channels, drains and levees within the project area.

Adequacy of data

The short late dry season survey is inadequate in that it does not give a complete picture of the aquatic fauna (freshwater and estuarine). It does provide a good insight as to the fauna which might be present in the Keep and Sandy freshwater drainages, with possibly another 10 fish species not yet recorded.

The estuarine fauna in particular (fauna restricted to downstream of all impacts) must be surveyed, as this information is almost completely lacking. The estuaries of the Keep River and Sandy Creek are extensive and probably complex. They may support between 100-200 species of fish, some of which will be of commercial and recreational importance (e.g. barramundi, jewfish,

threadfin, snapper). The benthic estuarine invertebrates should be surveyed, as information is totally lacking.

An estuarine faunal survey needs to be undertaken. The Keep estuary is downstream of all the potential changes (in flow, chemistry etc.) and should therefore be monitored. However, given the dynamic nature of estuaries in the Northern Territory (e.g. at least 8 m tidal range, sediments mobilised during wet season flows), it may not be easy to distinguish between natural and man-made changes, unless good baseline data is acquired before construction and monitoring is carried out.

Further work on the aquatic fauna should continue, and monitoring sites at a number of localities, including a range of control sites, should be established as soon as possible, so that “before” data can be collected. Species assemblages of residential fish and benthic invertebrates could be monitored concurrently with hydrological and chemical monitoring.

Conservation areas

In the following discussion, it must be borne in mind that only five main areas on each drainage system (Keep and Sandy) were sampled, and that potentially significant areas were not visited due to time constraints.

At present, Spirit Hill Station is owned by the NT Land Corporation and managed by the Parks and Wildlife Commission of the Northern Territory (PWCNT), and all or portions of the station may be incorporated into Keep River National Park in the future. The Keep River National Park provides protection for most of the upper catchment of the Keep River. However, two significant refuge areas, Alligator Hole and Milligan Lagoon, are north of the present park boundary. These two areas are different (see descriptions and illustrations above) and are considerable waterbodies which probably rarely dry up if ever (are about 2-3 m deep in the dry season), forming important refuges for aquatic fauna and some terrestrial fauna (such as waterbirds). Alligator Hole and Milligan Lagoon should be protected from changes; i.e. no drains, levees, or channels etc should be constructed upstream of or enter them. These two localities and their associated drainage systems (seasonal creeks and surrounding topography) would make good control sites for monitoring and comparative purposes. They would also make good inclusions within Keep River National Park.

Sandy Creek, although smaller than the Keep River, has several significant localities. Emerald Spring, and other spring-fed sites on the escarpment outcroppings around the Banana Hill area, are of conservation significance in that they are refuge areas for aquatic fauna and some terrestrial fauna such as the Splendid Tree-frog (*Litoria splendida*). These outcroppings (to east, west and south of Banana Hill) could form a conservation/protected area. Further work would be required to establish if any of these areas could withstand increased visitation pressure.

One area of Sandy Creek which is already visited is Augustus Hole, a long 2.7 m deep permanent section of the creek. Man-made rubbish and campsites were observed. This spectacular waterhole will certainly attract more visitors as the development proceeds and will need to be managed as soon as practicable. For example, a “catch-and-release” fishing requirement would ensure that there will always be sooty grunTERS to take a lure.

The development of Ord River Stage 2 will increase recreational fishing and visitation, which should be considered while planning monitoring programmes. It is unknown what the effect may be of the increased river flow on the endangered sawfish or any of the aquatic fauna. The entire project is basically an experiment on a whole river system, which must be carefully monitored and managed to remove the likelihood of negative impacts.

REFERENCES

- Allen, G.R. 1982. *Inland fishes of Western Australia*. Western Australian Museum, Perth.
- Arthington, A.H. and Lloyd, L.N. 1989. Introduced poeciliids in Australia and New Zealand. Pp 333-348 In: Meffe, G.K. and Snelson, F.F. *Ecology and evolution of livebearing fishes (Poeciliidae)*. Prentice Hall, New Jersey.
- Coombes, K. 1996. Population dynamics and ecology of a suite of Atyidae (Crustacea: Decapoda) species in freshwater ecosystems in the Darwin region. Unpublished B. Sc. (Hons) thesis, Northern Territory University.
- George, R.W. and Jones, D.S. 1982. *The fiddler crabs of Australia (Ocypodidae: Uca)*. Records of the Western Australian Museum, Supplement No. 14: 1-99.
- Hanley, J.R. and Banks, A.L. 1995. Survey of mangrove molluscs and other invertebrates on tidal creeks in the Roper River region, Gulf of Carpentaria. MAGNT Marine Ecology Unit Technical Report 95/2 (Unpublished).
- Horner, P. and Fisher, A. 1998. *Ctenotus rimacola* sp. nov. (Scincidae), a new species of lizard with two allopatric subspecies, from the Ord-Victoria region of northwestern Australia. *Records of the Western Australian Museum* **19**: 187-200.
- Hutchins, J.B. 1981. Freshwater fish fauna of the Mitchell Plateau area, Kimberley, Western Australia. Pp 229-247. In: *Biological survey of Mitchell Plateau and Admiralty Gulf, Kimberley: papers resulting from a joint field expedition to Mitchell Plateau, Kimberley*. Western Australian Museum, Perth.
- Larson, H.K. In prep. The fish fauna of the Northern Territory: an annotated checklist. *The Beagle, Records of the Museums and Art Galleries of the Northern Territory*.
- Larson, H.K. 1995. Diversity of Fishes in Ranger and Comparison Billabongs, Kakadu National Park: Final Report. Report to CSIRO, Canberra.
- Larson, H.K. 1996. Report on the Biological Resource Survey of the Roper River System, Gulf of Carpentaria, Northern Territory, Australia: Coastal and Estuarine Fishes. Report to Mount Isa Mines Holdings, Brisbane.
- Larson, H.K. 1997. Report to Parks Australia North, on the estuarine fish inventory of Kakadu National Park, Northern Territory, Australia.
- Larson, H.K. and Martin, K.C. 1990. *Freshwater fishes of the Northern Territory*. Northern Territory Museum of Arts and Sciences, Handbook No.1, Darwin.
- Larson, H.K. and Williams, R.S. 1997. Darwin Harbour fishes: a survey and annotated checklist. Pp. 339-380. In: Hanley, J.R., Caswell, G., Megirian, D. and Larson, H.K. (eds) *Proceedings of the Sixth International Marine Biological Workshop. The Marine Flora and Fauna of Darwin Harbour, Northern Territory, Australia*. Museums and Art Galleries of the Northern Territory and Australian Marine Sciences Association, Perth.
- Last, P.R. and Stevens, J.D. 1994. *Sharks and rays of Australia*. CSIRO Australia.
- Midgley, S.H. 1981. The Victoria River, the Fitzmaurice River, the Keep River, a biological resource study. Report to the Fisheries Division, Department of Primary Production of the Northern Territory (Unpublished)

- Nelson, J.S. 1976. *Fishes of the world*. John Wiley and Sons, New York.
- Press, T., Brock, J. and Andersen, A. 1995. Fauna. In: Press, T., Lea, D., Webb, A., and Graham, A. (eds) *Kakadu. Natural and cultural heritage and management*. Pp. 167-216. Australia Nature Conservation Agency, Darwin.
- Russell, B.C. and Houston, W.E. 1989. Offshore fishes of the Arafura Sea. *The Beagle, Records of the N.T. Museum of Arts and Sciences* **6**(1): 69-84.
- Short, J.W. In prep. Identification guide to Australian *Macrobrachium*. Queensland Museum, Brisbane.
- Smith, M.J. and Williams, W.D. 1982. Taxonomic revision of the Australian genus *Caridinides* Calman (Crustacea: Decapoda: Atyidae). *Australian Journal of Marine and Freshwater Research* **33**: 575-587.
- Wells, A.G. 1995. Groupings of tidal river systems in northern Australia based on mangrove species. *Proceedings of the Linnean Society of New South Wales* **115**: 135-148.

KEEP RIVER AQUATIC FAUNA SURVEY
APPENDIX 1 – LIST OF BIRD SPECIES

KEEP RIVER AQUATIC FAUNA SURVEY
APPENDIX 1 – LIST OF BIRD SPECIES

APPENDIX I. BIRD SPECIES RECORDED IN KEEP RIVER / SANDY CREEK AREA, OCTOBER 1998

1 = "Bucket Springs", 4-5 Oct.; 2 = Alligator Waterhole, 6 Oct.; 3 = Milligan Lagoon, 7 Oct.; 4 = Augustus Hole, 7-8 Oct.; 5 = Emerald Spring, 8 Oct.; 6 = Keep River / Oakes Creek junction, 9-10 Oct.; 7 = Keep River (old airstrip /swamp), 10 ct.; 8 = Sandy Creek (billabong), 10 Oct.; 9 = Sandy Creek estuary, 11 Oct.; 10 = Sandy Creek tributary, 11 Oct.; 11 = Keep River at road crossing, 11 Oct.

SPECIES Common name	Scientific name	SITES										
		1	2	3	4	5	6	7	8	9	10	11
Magpie Goose	<i>Anseranas semipalmata</i>	.	+	+	.	.	.	.	.	.	.	.
Pacific Black Duck	<i>Anas superciliosa</i>	.	.	+	.	.	.	+	.	.	.	.
Radjah Shelduck	<i>Tadorna radjah</i>	.	.	+	.	.	.	.	+	.	.	.
Australasian Grebe	<i>Tachybaptus novaehollandiae</i>	.	+	.	.	.	.	+	.	.	.	.
Darter	<i>Anhinga melanogaster</i>	.	.	+	+	.	+	.	.	.	.	.
Little Pied Cormorant	<i>Phalacrocorax melanoleucos</i>	.	.	+	+	+	.	.	.	.	.	.
Australian Pelican	<i>Pelecanus conspicillatus</i>	.	.	.	.	.	+	+	.	.	.	.
Great Egret	<i>Ardea alba</i>	.	.	.	.	.	+	.	.	.	.	.
Intermediate Egret	<i>Ardea intermedia</i>	.	.	+	.	.	.	.	.	.	.	.
Nankeen Night Heron	<i>Nycticorax caledonicus</i>	.	+	.	+	.	.	.	.	.	.	.
Australian White Ibis	<i>Threskiornis molucca</i>	.	.	+	.	.	.	.	.	.	.	.
Straw-necked Ibis	<i>Threskiornis spinicollis</i>	.	.	+	.	.	.	.	.	.	.	.
Royal Spoonbill	<i>Platalea regia</i>	.	.	.	.	.	.	+	.	.	.	.
Black-necked Stork	<i>Ephippiorhynchus asiaticus</i>	.	.	.	.	.	+	.	.	.	.	.
Osprey	<i>Pandion haliaetus</i>	.	.	.	+	.	.	.	.	.	.	.
Whistling Kite	<i>Haliastur sphenurus</i>	.	+	.	+	.	+	.	+	+	.	+
White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	.	.	.	+	+	+	.	+	.	.	+
Brown Goshawk	<i>Accipiter fasciatus</i>	.	+	.	+	.	.	.	.	.	.	.
Collared Sparrowhawk	<i>Accipiter cirrhocephalus</i>	.	.	.	.	.	.	.	+	.	.	+
Wedge-tailed Eagle	<i>Aquila audax</i>	.	.	.	.	+	.	.	.	.	.	.
Brolga	<i>Grus rubicunda</i>	.	.	+	.	.	.	.	.	.	.	.
Australian Bustard	<i>Ardeotis australis</i>	.	.	.	+	.	.	+	.	.	.	.
Marsh Sandpiper	<i>Tringa stagnatilis</i>	.	.	.	.	.	.	+	.	.	.	.
Common Greenshank	<i>Tringa nebularia</i>	.	.	+	.	.	.	.	.	.	.	.
Common Sandpiper	<i>Actitis hypoleucos</i>	.	.	.	+	.	.	.	.	.	.	.
Sharp-tailed Sandpiper	<i>Calidris acuminata</i>	.	.	.	.	.	.	+	.	.	.	.
Bush Stone-curlew	<i>Burhinus grallarius</i>	.	.	.	+	.	+	.	.	.	.	.
Black-winged Stilt	<i>Himantopus himantopus</i>	.	.	.	.	.	+	.	.	.	.	.
Red-kneed Dotterel	<i>Erythronyx cinctus</i>	.	.	+	.	.	.	+	.	.	.	.
Masked Lapwing	<i>Vanellus miles</i>	.	.	+	.	.	+	+	.	.	.	.
Australian Pratincole	<i>Stiltia isabella</i>	.	.	.	.	.	.	+	.	.	.	.
Silver Gull	<i>Larus novaehollandiae</i>	.	.	.	.	.	.	.	.	+	.	.
Caspian Tern	<i>Sterna caspia</i>	.	.	.	.	.	+	.	.	.	.	.
Common Bronzewing	<i>Phaps chalcoptera</i>	.	.	.	.	.	.	.	+	.	.	.
Crested Pigeon	<i>Ocyphaps lophotes</i>	.	.	+	.	.	.	+	+	.	.	.
White-quilled Rock-Pigeon	<i>Petrophassa albipennis</i>	.	.	.	+	.	.	.	.	.	.	.
Peaceful Dove	<i>Geopelia striata</i>	+	+	+	+	.	+	+	+	.	.	.
Bar-shouldered Dove	<i>Geopelia humeralis</i>	+	+	+	+	.	+	.	+	.	.	.
Red-tailed Black-Cockatoo	<i>Calyptrorhynchus banksii</i>	.	.	+	+	.	.	+	+	.	.	.
Galah	<i>Cacatua roseicapilla</i>	+	.	.	+	.	.	.	+	.	.	.

KEEP RIVER AQUATIC FAUNA SURVEY
APPENDIX 1 – LIST OF BIRD SPECIES

SPECIES Common name	Scientific name	SITES										
		1	2	3	4	5	6	7	8	9	10	11
Little Corella	<i>Cacatua sanguinea</i>	+	+	.	.	.	.	.	+	.	.	+
Sulphur-crested Cockatoo	<i>Cacatua galerita</i>	.	+	.	+	.	.	.	.	.	.	+
Cockatiel	<i>Nymphicus hollandicus</i>	.	.	.	.	.	+	+	.	.	.	.
Rainbow Lorikeet	<i>Trichoglossus haematodus</i>	+	+	.	+	.	.	.	+	.	.	.
Red-winged Parrot	<i>Aprosmictus erythropterus</i>	+	.	.	.	.	+	.	.	.	.	.
Brush Cuckoo	<i>Cacomantis variolosus</i>	.	.	.	+	.	+	.	.	.	.	.
Common Koel	<i>Eudynamys scolopacea</i>	.	.	.	+	.	.	.	.	.	.	.
Channel-billed Cuckoo	<i>Scythrops novaehollandiae</i>	.	.	.	+	.	.	.	.	.	.	.
Pheasant Coucal	<i>Centropus phasianinus</i>	+	.	.	+	.	.	+	.	.	.	.
Barking Owl	<i>Ninox connivens</i>	.	.	.	.	.	.	.	.	.	.	.
Southern Boobook	<i>Ninox novaeseelandiae</i>	.	.	.	+	.	+	.	+	.	.	.
Azure Kingfisher	<i>Alcedo azurea</i>	.	.	.	+	.	.	.	.	.	.	+
Blue-winged Kookaburra	<i>Dacelo leachii</i>	+	+	+	+	.	+	.	+	.	.	+
Forest Kingfisher	<i>Todiramphus macleayi</i>	.	.	.	+	.	+	.	+	.	.	.
Sacred Kingfisher	<i>Todiramphus sanctus</i>	.	+	.	.	.	.	.	.	.	+	.
Rainbow Bee-eater	<i>Merops ornatus</i>	+	+	+	.	+	.	+	+	+	.	.
Dollarbird	<i>Eurystomus orientalis</i>	+	+	+	+	.	+	.	+	.	.	+
Red-backed Fairy-wren	<i>Malurus melanocephalus</i>	.	.	.	.	.	.	.	.	+	.	.
Little Friarbird	<i>Philemon citreogularis</i>	.	+	.	.	.	.	.	.	.	.	.
Blue-faced Honeyeater	<i>Entomyzon cyanotis</i>	+	+	.	.	.	.	.	.	.	.	.
Singing Honeyeater	<i>Lichenostomus virescens</i>	+	.	.	.	.	.	.	.	.	.	.
White-gaped Honeyeater	<i>Lichenostomus unicolor</i>	+	.	.	+	.	.	.	.	.	.	.
White-throated Honeyeater	<i>Melithreptus albogularis</i>	.	.	.	.	.	.	.	.	.	.	+
Brown Honeyeater	<i>Lichmera indistincta</i>	+	.	.	+	.	.	.	.	.	.	+
Rufous-throated Honeyeater	<i>Conopophila rufogularis</i>	.	.	.	.	.	.	.	.	.	.	+
Bar-breasted Honeyeater	<i>Ramsayornis fasciatus</i>	.	.	.	+	.	.	.	.	.	.	.
Banded Honeyeater	<i>Certhionyx pectoralis</i>	+	.	.	.	.	.	.	.	.	.	+
Jacky Winter	<i>Microeca fascinans</i>	.	.	.	.	.	.	+	.	.	.	.
White-browed Robin	<i>Poecilodryas superciliosa</i>	.	.	.	.	.	.	.	.	.	.	+
Grey-crowned Babbler	<i>Pomatostomus temporalis</i>	+	.	.	.	.	+	+	.	.	+	.
Rufous Whistler	<i>Pachycephala rufiventris</i>	.	.	.	.	.	.	.	.	.	+	.
Little Shrike-thrush	<i>Colluricincla megarrhyncha</i>	.	.	.	.	.	.	.	.	.	+	.
Satin Flycatcher	<i>Myiagra cyanoleuca</i>	+	.	.	.	.	.	.	.	.	.	.
Shinning Flycatcher	<i>Myiagra alecto</i>	.	.	+	+	.	.	.	.	.	.	.
Restless Flycatcher	<i>Myiagra inquieta</i>	.	+	.	.	.	+	.	+	.	.	.
Magpie-lark	<i>Grallina cyanoleuca</i>	.	+	+	+	.	+	+	+	+	.	.
Northern Fantail	<i>Rhipidura rufiventris</i>	.	.	.	+	.	+	.	.	.	.	.
Willie Wagtail	<i>Rhipidura leucophrys</i>	.	+	+	.	.	+	.	.	+	+	.
Spangled Drongo	<i>Dicrurus bracteatus</i>	.	.	.	.	.	.	.	.	.	.	+
Olive-backed Oriole	<i>Oriolus sagittatus</i>	.	+	.	.	.	.	.	.	.	.	.
Black-faced Cuckoo-shrike	<i>Coracina novaehollandiae</i>	.	.	.	+	.	.	.	.	+	.	.
White-bellied Cuckoo-shrike	<i>Coracina papuensis</i>	.	.	.	.	.	+	.	.	.	.	.
White-breasted Woodswallow	<i>Artamus leucorhynchus</i>	+	.	.	.	.	.	.	.	.	.	.
Black-faced Woodswallow	<i>Artamus cinereus</i>	.	+	.	.	.	.	.	.	.	.	.
Little Woodswallow	<i>Artamus minor</i>	.	.	.	.	.	+	.	.	.	.	.
Pied Butcherbird	<i>Cracticus nigrogularis</i>	+	+	+	+	.	+	+	+	.	.	.
Torresian Crow	<i>Corvus orru</i>	+	+	+	+	.	+	.	+	.	.	.
Great Bowerbird	<i>Chlamydera nuchalis</i>	+	+	+	.	.	.	.	+	.	.	+
Double-barred Finch	<i>Taeniopygia bichenovii</i>	.	+	.	+	.	+	.	.	.	.	+
Long-tailed Finch	<i>Poephila acuticauda</i>	.	.	+	.	.	.	.	.	.	.	.
Masked Finch	<i>Poephila personata</i>	.	.	+	.	.	.	.	.	.	.	.
Crimson Finch	<i>Neochima phaeton</i>	+	.	.	+	.	.	.	.	.	.	.
Mistletoebird	<i>Dicaeum hirundinaceum</i>	+	.	.	+	.	.	.	.	.	.	.

APPENDIX II. AMPHIBIAN, REPTILE AND MAMMAL SPECIES RECORDED IN KEEP RIVER / SANDY CREEK AREA, OCTOBER 1998

1 = “Bucket Springs”, 4-5 Oct.; 2 = Alligator Waterhole, 6 Oct.; 3 = Milligan Lagoon, 7 Oct.; 4 = Augustus Hole, 7-8 Oct.; 5 = Emerald Spring, 8 Oct.; 6 = Keep River / Oakes Creek junction, 9-10 Oct.; 7 = Keep River (old airstrip /swamp), 10 Oct.; 8 = Sandy Creek (billabong), 10 Oct.; 9 = Sandy Creek estuary, 11 Oct.; 10 = Sandy Creek tributary, 11 Oct.; 11 = Keep River at road crossing, 11 Oct.

Species		Sites										
Common name	Scientific name	1	2	3	4	5	6	7	8	9	10	11
AMPHIBIA												
Copland's Rock Frog	<i>Litoria coplandi</i>	.	+	.	.	.	.	.	.	.	.	.
Peter's Frog	<i>Litoria inermis</i>	.	.	.	+	.	.	.	.	.	.	.
Rockhole Frog	<i>Litoria meiriana</i>	.	.	.	+	.	.	.	.	.	.	.
Rocket Frog	<i>Litoria nasuta</i>	.	.	.	+	.	.	.	.	.	.	.
Pale Frog	<i>Litoria pallida</i>	.	+	.	+	.	.	.	+	.	.	.
Roth's Tree-frog	<i>Litoria rothii</i>	+	.	.	+	.	.	.	+	.	.	.
Red Tree-frog	<i>Litoria rubella</i>	.	+	.	+	.	.	.	+	.	.	.
Tornier's Frog	<i>Litoria tornieri</i>	+	.	.	+	.	.	.	.	.	.	.
Wotjulum Frog	<i>Litoria wotjulumensis</i>	+	.	.	.	.	.	.	.	.	.	.
Froglet	<i>Crinia sp.</i>	.	.	.	+	.	.	.	+	.	.	.
Ornate Burrowing Frog	<i>Limnodynastes ornatus</i>	+	.	.	+	.	.	.	+	.	.	.
REPTILIA												
Freshwater Crocodile	<i>Crocodylus johnstoni</i>	+	+	.	.	.	.	.	.	.	.	.
Top-end Dtella	<i>Gehyra australis</i>	+	.	.	.	+	.	.	.	.	.	.
Bynoe's Prickly Gecko	<i>Heteronotia binoei</i>	.	.	.	.	.	.	.	.	.	.	.
Northern Two-line Dragon	<i>Diporiphora bilineata</i>	+	.	.	.	.	.	.	.	.	.	.
Gilbert's Dragon	<i>Lophognathus gilberti</i>	.	.	.	+	.	+	.	+	.	.	.
Bauxite Rainbow-skink	<i>Carlia amax</i>	+	+	.	.	+	.	.	.	.	.	.
Striped Rainbow-skink	<i>Carlia munda</i>	.	.	.	+	.	.	.	.	.	.	.
Arboreal Snake-eyed Skink	<i>Cryptoblepharus plagiocephalus</i>	+	+	.	.	.	.	.	+	.	.	.
Douglas' Skink	<i>Glaphyromorphus douglasi</i>	.	.	.	.	.	.	+	.	.	.	.
Merten's Water Monitor	<i>Varanus mertensi</i>	.	.	.	+	+	.	.	.	.	.	.
Mitchell's Water Monitor	<i>Varanus mitchelli</i>	+	+	.	.	.	.	.	.	.	.	.
Children's Python	<i>Liasis childreni</i>	.	.	+	.	.	.	.	.	.	.	.
Common Tree Snake	<i>Dendrelaphis punctulata</i>	+	.	.	.	.	.	.	.	.	.	.
MAMMALIA												
Agile Wallaby	<i>Macropus agilis</i>	+	.	.	.	.	.	.	.	.	.	+
Short-eared Rock-wallaby	<i>Petrogale brachyotis</i>	+	.	.	.	+	.	.	.	.	.	.
Grassland Melomys	<i>Melomys burtoni</i>	+	.	.	.	.	.	.	.	.	.	.
Little Red Flying-fox	<i>Pteropus scapulatus</i>	.	+	.	.	.	.	.	.	.	.	+
Common Sheath-tail-bat	<i>Taphozous georgianus</i>	.	.	.	.	+	.	.	.	.	.	.

ANNEXE TO MAGNT RESEARCH REPORT

No. 4

KEEP RIVER AQUATIC FAUNA SURVEY

Report to KINHILL PTY LTD

By

GRAHAM BROWN AND HELEN LARSON

KEEP RIVER AQUATIC INSECTS

KEEP RIVER AQUATIC INSECTS

The final report to Kinhill on the aquatic fauna survey of the Keep River area was submitted in March, 1999. Due to circumstances beyond our control, it was not possible to have the aquatic insects identified in time for inclusion in the report. This annexe should be read together with the main report, in which methods of collection are given, as are descriptions and illustrations of all sites sampled. The annotated list below refers to collecting sites by field number (eg. HL 98-39). All insects were identified by Dr Graham Brown of the Department of Primary Industries and Fisheries, Darwin (formerly of the Museums and Art Galleries of the Northern Territory).

Relevant Collecting Sites

HL 98-35

Keep River National Park, "Bucket Spring" by northern park border, at small open pool in unnamed creek fed by spring flowing from escarpment. 15° 44' 47" S 129° 10' 18" E. Water clear, 27.7°C, 0.2 ppt, 425.9 µs, 1.5m deep, current slow. Substrate rocks, sand, rubble, leaf litter and logs. Bright green sponges present on some limestone rocks (Spongillidae, probably *Radiospongilla* sp.). Aquatic vegetation of mixed grasses, reeds (*Eleocharis*), and taro (*Colocasia esculenta*) along edges. Shore steep sandy-clay banks, with few big *Melaleuca*, open woodland behind. 5 October 1998. 0830-1000 hrs. Coll. H. Larson, by scoopnet, hand.

HL 98-37

Keep River National Park, "Bucket Spring" by northern park border, at very shallow pool further downstream from previous station; creek flowing through rush/grass thickets at either end of pool. 15° 44' 58" S 129° 09' 45" E. Water clear, 28.9°C, 443.9 µs, pH 7.6, 0.25 m deep, current slow. Substrate sand, leaf litter. Aquatic vegetation reduced; *Marsilea* sp. in water, small amount of reeds (*Eleocharis*), grasses and taro (*Colocasia esculenta*) along edges. Shore sloping sandy-clay banks, with *Melaleuca*, *Barringtonia acutangula* and *Nauclea orientalis*, with open woodland behind. 5 October 1998. 1100-1200 and 2100-2215 hrs. Coll. H. Larson and P. Horner, by scoopnet and dipnets.

HL 98-40

Keep River drainage, Milligan Lagoon, a large open curved isolated billabong of the Keep River, in blacksoil plains. 15° 37' 17" S 129° 00' 20" E. Water somewhat turbid yellow-grey colour, 31.1°C, 0 ppt, 82.1µs, pH 7.2, about 1.5 m deep, no current. Substrate thick deep mud, leaf litter. Aquatic vegetation of *Nymphaea* (*N. macrosperma* or *N. violacea*), *Hydrilla verticillata* and *Chara* sp., forming dense mats. Bright green spiky sponge on vegetation (Spongillidae, probably *Radiospongilla* sp.). Shore open sloping blacksoil banks, with short grasses, *Barringtonia acutangula* and *Lysiphyllum cunninghamii*, open woodland behind. 7 October 1998. 1130-1230 hrs. Coll. H. Larson, by scoopnet.

HL 98-41

Sandy Creek, Augustus Hole, a large waterhole in main creek bed. 15° 31' 31" S 129° 19' 11" E. Water clear, 32.7°C, 0.1 ppt, 311.9 µs, pH 7.6, 1.5 m deep, no current. Substrate coarse sand, leaf litter. Aquatic vegetation absent. Shore on east bank a rocky gorge, on west bank steep sandy banks, with riparian vegetation mostly of *Pandanus spiralis*, *Melaleuca*, *Barringtonia acutangula* and *Nauclea orientalis*, open woodland behind. 7 October 1998. 1700-1900 and 2030-2130 hrs. Coll. H. Larson and P. Horner, by scoopnet and hook and line.

HL 98-42

Sandy Creek, Augustus Hole, at south end of main waterhole where it meets small spring-fed creek flowing over small boulders, among grassy banks. 15° 31' 42" S 129° 19' 30" E. Water clear, 30.8°C, 0.2 ppt, 312.2 µs, pH 7.6, 0.5-1.5 m deep, current slow to moderate. Substrate rocks, sand, small boulders, *Melaleuca* leaf litter. Some green ?*Radiospongilla* sp. and algae present on rocks. Aquatic vegetation practically absent, some small *Eleocharis* sp. and grasses. Shore open, almost no banks, with grasses, few *Pandanus spiralis* and *Melaleuca* sp., open woodland behind. 8 October 1998. 0930-1030 hrs. Coll. H. Larson, by scoopnet.

HL 98-43

Sandy Creek, Augustus Hole, at north end of main waterhole, forming series of small open sandy and rocky pools joined by narrow stream. 15° 31' 00" S, 129° 18' 46" E. Water clear, 30.9°C, 0.2 ppt, 333.2 µs, pH 7.6, 0.5 m deep, current slow to moderate. Substrate white sand, rocks, leaf litter. Aquatic vegetation practically absent, some small *Eleocharis* sp. Shore low grassy banks, with grasses, overhanging *Pandanus spiralis* and *Melaleuca* sp., open woodland behind. 8 October 1998. 1115-1145 hrs. Coll. H. Larson, by scoopnet.

HL 98-45

Sandy Creek drainage, Emerald Spring, large spring-fed pool at base of vertical sandstone cliff. 15° 31' 59" S, 129° 15' 55" E. Water greenish, relatively clear, 32°C, 0 ppt, 20.8 µs, pH 6.4, about 2.5 m deep, no current. Substrate sand, rock, leaf litter. Aquatic vegetation green algae on rocks and plant rootlets. Shore half sandstone cliff, half sloping sandy banks bound by rootlets, few *Melaleuca*, with open woodland behind. 8 October 1998. 1600-1700 and 2045-2130 hrs. Coll. H. Larson, by scoopnet.

HL 98-46

Keep River system, Oakes Creek, at junction with Keep River, creek broken into series of shallow pools. 15° 19' 19" S, 129° 05' 21" E. Water turbid, 35.1°C, 48.8 ppt, 0.5 m deep, no current. Substrate sand, rock, mud layer mixed with sand. Aquatic vegetation absent, green algal bloom in some pools. Last pool in which fish were found, about 0.5 km up creek from junction, was 40.5°C, 42.5 ppt. Shore low sandy banks of low grasses and small bushy *Melaleuca* sp., low open savannah woodland behind. 9 October 1998. 1430-1515 hrs. Coll. H. Larson, by scoopnet.

HL 98-48

Sandy Creek, billabongs in broad rounded sandy un-named creek bed broken into series of pools 0.25-1 km long. 15° 23' 38" S, 129° 11' 10" E. Water clear greenish, 32.8°C, 0.1 ppt, 99.5 µs, pH 7.2, 1.5 m deep, no current. Substrate sand, leaf litter, thick vegetation, logs and sticks. Aquatic vegetation *Chara* sp., *Urticularia australis*, *Najas tenuifolia*, *Nymphaea* (*N. macrosperma* or *N. violacea*); *Enteromorpha* sp. and other green algae forming blooms at ends of some pools. Shore low to steeply sloping sandy banks, grassy, with scattered *Eucalyptus* and *Melaleuca*, open woodland behind. 10 October 1998. 1530-1700, 2000-2100 hrs. Coll. H. Larson and P. Horner, by 20' seine and scoopnets.

HL 98-51

Sandy Creek tributary, isolated pool in narrow eroded channel, one of several, rest of channel dry. 15° 19' 11" S, 129° 13' 51" E. Water rather turbid greenish, 39°C, 61.1 ppt, 0.5-1 m deep, no current. Substrate clay, mud, logs, many fallen trees. Aquatic vegetation absent. Shore steep clay-mud banks full of tree roots, with low open woodland behind, mostly *Melaleuca*. 11 October 1998. 1245-1300 hrs. Coll. H. Larson, by scoopnet.

HL 98-52

Keep River, on south side of bridge where Legune Station road crosses river, river broken into series of large pools. 15° 24' 23" S, 129° 03' 45" E. Water somewhat turbid, greenish, 32.5°C, 0.1 ppt, 163.1 µs, pH 7.2, at least 1 m deep, no current. Substrate rock slabs, rocks, gravel, sand, logs and leaf litter. Aquatic vegetation absent. Shore steep blacksoil banks with *Pandanus* ?*aquaticus*, *Barringtonia acutangula* and *Melaleuca* sp., open woodland behind. 11 October 1998. 1415-1515 hrs. Coll. H. Larson and P. Horner, by scoopnet and hook and line.

HEMIPTERA – BUGS

Belostomatidae – Giant water-bugs

These are large bugs, with two species each of *Lethocerus* and of *Diplonychus* occurring in Australia. Only *Diplonychus eques* was collected, although the two species of *Lethocerus* would also be expected to occur in the region. All three species are common and widespread in the Top End, including Keep River.

***Diplonychus eques* (Dufour)**

HL 98-39, HL 98-40, HL 98-41, HL 98-48

Corixidae – Water boatmen

Thirty-one species placed in five genera are recorded from Australia. Of these, only two genera, *Agraptocorixa* and *Micronecta*, are recorded from the Northern Territory. Only *Agraptocorixa halei* was collected, although species of the smaller-sized *Micronecta* would be expected to occur. Both groups including *A. halei* are common and widespread in the Top End, including Keep River.

Agraptocorixa halei Hungerford

HL 98-39, HL 98-40, HL 98-48, HL 98-52

Galastoceridae – Toad bugs

Twenty-three species are recorded from Australia, with at least three occurring in the Northern Territory. They are not commonly collected, and little is known of their biology other than they are predatory, and that most are associated with water. *Nerthra luteovara* occurs from north Queensland through the Top End to the Kimberley district of Western Australia. The specimens were collected by disturbing the sand near the water's edge with hands and feet. This resulted in specimens emerging from the sand, which appears to be a behaviour pattern not previously recorded for the group.

Nerthra luteovara (Distant)

HL 98-41

Gerridae – Water striders

Thirty-two species are recorded from Australia, of which at least 20 occur in the Northern Territory. These include eight or nine species of the marine genus *Halobates*. Of the five species collected, all are common in the Top End, and all except *Aquarius fabricii* have been recorded previously from the Keep River. *Limnogonus luctuosus* (Montrouzier) is another common species that is known to occur at Keep River, although it was not collected. Two other species, *Calyptobates minimus* Polhemus and Polhemus, and *L. windi* Hungerford and Matsuda, may also occur but both are rare in this part of their distributions. Also expected to occur would be several species of *Halobates* in various marine habitats.

Aquarius fabricii Andersen

HL 98-43

Limnogonus fossarum gilguy Andersen and Weir

HL 98-39

Limnogonus hungerford Andersen and Weir

HL 98-43

Rhagadotarsus anomalus Polhemus and Karunaratne

HL 98-41, HL 98-52

Tenagogerris pallidus Anderson and Weir

HL 98-35

Nepidae – Water scorpions

Eight Australian species are known, seven of which are recorded from the Northern Territory. All three species are widespread throughout the Top End with *Laccotrephes tristis* also occurring throughout much of Australia. Most of the other Australian species have either limited distributions, or are known from only a few specimens.

Cercomatus brevipes australis Lansbury

HL 98-37

Laccotrephes trsitis (Stål)

HL 98-37, HL 98-39

Randatra diminuta Montandon

HL 98-35, HL 98-37, HL 98-40, HL 98-41, HL 98-45, HL 98-48

Notonectidae – Backswimmers

Forty species are described from Australia. These are placed in six genera of which three recorded from the Northern Territory and only two are expected to occur at Keep River. Most species are placed in *Anisops* which also includes numerous undescribed species. *Anisops nasuta* and *Enitheres loria* are common in the Top End and therefore were expected to occur at Keep River.

Anisops nasuta Fieber

HL 98-52

Anisops sp.

HL 98-52

Enitheres loria Brooks

HL 98-40, HL 98-48

COLEOPTERA – BEETLES

Dytiscidae – Predaceous diving beetles

This is one of the largest aquatic families with 185 Australian species of which at least 54 are recorded from the Northern Territory. Most of these species are common in the Top End.

Antiporus sp.?

HL 98-52

Cybister godeffroyi Wehnecke

HL 98-48

Eretes australia (Erichson)

HL 98-48

Hydaticus vittatus (Fabricius)

HL 98-39, HL 98-48

Megapons refriceps (Shap)

HL 98-48

Rhantaticus congestus (Klug)

HL 98-39

Hydrophilidae – Water scavenger beetles

Over 175 species are recorded from Australia, but the family is in need of taxonomic revision. Many species are common in the Top End, including those within the genus *Sternolophus*, which was represented in the survey by a single unidentified species.

Sternolophus sp.

Noteridae – Burrowing water beetles

Five species are recorded from Australia. Most species occur in the northern part of the continent, with *Hydrocanthus* and *australasine* being common in the Top End.

Hydrocanthus australasine When
HL 98-48

ORTHOPTERA – GRASSHOPPERS AND CRICKTETS

Tridactylidae – Pygmy mole crickets

Nine species of pygmy mole crickets are recorded from Australia, with two species occurring in the Top End. They are not aquatic, although *Tridactylus australicus* can swim. Pygmy mole crickets are reliant on permanent fresh water, and are often abundant near permanent streams and ponds. Only one species, *T. australicus*, was collected, and is variable in morphology, with several geographical races.

Tridactylus australicus Mjöberg
HL 98-48

DISCUSSION

Fourteen species of aquatic bugs (Hemiptera), eight species of aquatic beetles (Coleoptera) and one pygmy mole cricket (Orthoptera) were collected. Most, if not all of these species, are common throughout much of the Top End and would be expected to occur at Keep River. It is not possible to comment on the distribution and abundance of the few species that could not be identified to species level, and a lack of comments on these species is a reflection of the lack of available taxonomic information.

Several groups of aquatic insects were not collected during the survey due to time constraints. These include mayflies (Ephemeroptera), dragonflies (Odonata) and caddisflies (Trichoptera). Several other hemipteran and coleopteran families would also occur, such as the Hydrometridae (Hemiptera) and Gyrinidae (Coleoptera).

APPENDIX M

GROUNDWATER FAUNA SAMPLING IN THE KIMBERLEY

Groundwater fauna sampling in the Kimberley north of 16°S and east of 128°E.

**A report for Kinhill Pty Ltd pertaining to Stage 2 (M2): Ord River
Irrigation Area project**

**W.F. Humphreys
Museum of Natural Science**

August 1999

Summary

The Museum of Natural Science has undertaken limited sampling of stygofauna in the area in 1994 and 1998. A significant stygofauna is associated with the karstic landforms in the Devonian Reef system comparable to that found in the west Kimberley. Interstitial stygofauna is found in the alluvial deposits of the established part of the Ord Irrigation area (Ivanhoe Plain), including two families of bathynellid Syncarida (Crustacea). Bathynellids are also found in the proposed Ord River expansion project area (Cave Spring Gap and Weaber Plain). Owing to the characteristics of the sampling points little confidence is placed that the samples to hand represent the diversity of the stygofauna of the area sampled. No sampling has been undertaken on the Keep River Plain or the Knox Creek Plain which together comprise a large majority of the project area.

Introduction

Kinhill Pty Ltd requested, at short notice, a report on the stygofauna (aquatic subterranean fauna) known in the region of Stage 2 (M2): Ord River Irrigation Area project and in the immediately surrounding area. This report provides the distribution of stygofauna sampling sites, the associated fauna to the level of identification currently available and a discussion of the limitations to the data.

Identification of stygofauna

While the nature of the fauna can be determined largely from the typical morphology often found in stygal species, the stygofauna of Western Australia is largely unknown and predominantly undescribed, being newly found species or higher order taxa. This is also the case with the fauna reported here. Few specialists are available to determine and describe the fauna and most material can only be identified and described by specialist taxonomists located interstate or overseas.

It is important to clarify taxonomic relationships to establish the significance of potential impacts. For example, if a taxon is represented by a single species throughout the aquifer then localised drawdown or elevation of the groundwater surface, or other effects, are less likely to have significant impact, but if different and localised species occur then the danger will increase that any impacts may result in the loss of biodiversity.

Significance of stygofauna

Stygofauna is significant for a number of reasons. It includes rare and relict taxa which comprise a significant component of biodiversity. It is of considerable value to studies in zoogeography and the evolution of the Australian biota and landscape. Stygofauna play an essential role in ecosystem processes, by breaking down nutrients and recycling them through the food web. They may also play an important role in maintaining water quality through bioturbation, in much the same manner as earthworms contribute to the health of the soil. Stygofauna may be valuable indicators of threats to the integrity and sustainability of the groundwater system.

Habitat patchiness

The dispersion of stygofauna within an alluvial aquifer, as opposed to a karstic or fissured aquifer, is likely to be widespread but with individual species having patchy distributions owing to local variations in groundwater characteristics. Typically, downwelling and upwelling areas have different characteristics and changes to the water level (e.g. during flooding) may have profound effects on the distribution of organisms within the aquifer. Hence, a broad range of fauna will most likely only be detected by sampling across a wide geographical area and range of habitats. In the absence of knowledge of the hydrology of the system there is perforce a degree of chance involved in sampling. Hence, repeated sampling of a number and types of bores may be required to be reasonably confident, for example, that an apparent absence is real.

In some localities elsewhere, however, stygofauna appears to be genuinely absent in apparently suitable habitats. In the Millstream aquifer, for instance, the distribution of the spelaeogriphacean *Mangkurta mityula* Poore and Humphreys appears to be confined to a limited area of the calcrete aquifer, and absent from contiguous areas despite apparently similar hydrogeology, bore age and construction, and sampling effort. Thus stygofauna cannot be assumed to occur throughout the range of potential habitat (Poore and Humphreys 1998).

Bore Constructions

Detecting the presence of stygofauna may be dependant upon bore construction characteristics. Stygofauna is more likely to be detected in un-cased bores because the fauna is free to migrate directly into the bore cavity from the natural voids in the host rock or sediments. The efficacy of the case slotting in allowing fauna movement will likely depend, inter alia, on the slotting or screen size, its interval and depth, and whether or not the bore annulus is gravel packed. Slotting or gravel pack of small dimensions will inhibit or prevent the migration of stygofauna into the bore cavity, especially for macro-sized (> 1 mm) fauna. Fine sediments originating from the host rocks, or from the drilling process, may clog the slotting or interstitial spaces within the gravel pack and prevent the movement of fauna into the bore cavity. End caps on bore casings, or bentonite seals may also restrict the dispersal of fauna into the bore cavity.

The construction date of bores may also influence the ability to detect stygofauna. Newly constructed bores will contain unfavourable conditions for stygofauna due to retention of turbid or foreign waters, other fluids, or drilling clays, especially if they have not been developed. Older bores are more likely to harbour stygofauna as the water quality stabilises to that of the surrounding groundwater, and the fauna has been given time to disperse and colonise the bore cavity.

Lithology

The distribution of stygofauna is related, inter alia, to rock and sediment types, and the geological structure. Stygofauna habitat is best developed in karstic aquifers. Stygofaunal habitat may also occur in non-karstic rocks, or unconsolidated sediments, if suitable water-filled voids are present. In non-karstic rocks natural voids may be associated with structural features, such as fissures for example (fissured aquifer) (Gilbert et al. 1994). In unconsolidated sediments, the water-filled pores between grains of sediment, especially where these are sand-sized or larger, forms an extensive groundwater habitat (porous aquifer). Thus stygofauna may be present in gravels alongside and beneath water courses, as well as aquifers in alluvial or other sediments.

In Western Australia, stygofauna is frequently well developed where limestone and calcrete deserts occur, although in some karst areas such as the Nullarbor Plain macro fauna is largely absent. Stygofauna is known to be present in consolidated sediments alongside the Robe and Fortescue Rivers (Humphreys 1999; W.F. Humphreys, unpublished data) and sandstone springs in the Kimberley (Humphreys 1994; Wilson and Keable 1999).

Sampling methods

Stygofauna was sampled by using standard techniques as used successfully elsewhere (e.g. Humphreys, 1994). Bores were sampled for fauna using a haul plankton net with a 250 or 350 μ m mesh and of a diameter suitable for the bore – from 50 mm to 300 mm in diameter. Haul net samples were taken from the entire water column at each site. Samples were transported live to the laboratory and examined for fauna under a binocular dissecting microscope. Specimens were preserved in 70% ethanol and lodged with the Western Australian Museum of Natural Science.

Samples

Thirty-four sampling locations have been examined in the region in 1994 and 1998. Of these 11 sites contained undoubted stygofauna and another two sites contained fauna that is probably stygal (Tables 1 and 2). These sites range from the karstic limestone Devonian Reef system (Ningbing Range), to the alluvial aquifers associated with the former course of the Ord River through the Ivanhoe Plain, Cave Spring Gap and Weaber Plain. No samples are available from the extensive Keep River Plain or the Knox Creek Plain that together comprise the bulk of the project area.

Regional fauna

Aspects of the subterranean fauna of the west Kimberley was reported by Humphreys (1995, 1999). The Ningbing Range contains an undescribed family of flabelliferan isopods (Wilson and Ponder 1992) while the sandstone Durack Range to the west contains a phreatoicid isopod of a lineage that provides a link between those known from the fragments of Eastern Gondwana (Humphreys 1995; Wilson and Keable 1999), and thus contains information of great antiquity. To the east, the Gregory National Park in the Northern Territory contains protojanirid isopods (Asellota), a family newly found in Australia (G.D.F. Wilson, pers. comm, 1999) and elsewhere known from Sri Lanka and southern Africa.

Ord irrigation region

The Ivanhoe Plan alluvial aquifers contain undescribed species in two families of bathynellid syncarid Crustacea (Table 1) and a number of other probable stygofauna less widely collected (Table 2). The fauna on the Cave Spring Gap and the Weaber Plain has similar characteristics but the detailed identifications is unknown at this stage (Tables 1 and 2; Figure 1). It may be pertinent that there is a natural groundwater divide between the Ivanhoe Plain and the remainder of the Ord palaeodrainage channel that was sampled (R Puglisi, pers comm 1999). Such a groundwater divide separates quite distinct faunas in the Western Fortescue Plain (Poore and Humphreys 1998; Humphreys 1999; W.F. Humphreys unpublished). Furthermore, the groundwater salinity varies widely indifferent parts of the project area and this may have a major impact on the fauna it can support. While stygofauna is typically associated with freshwater (Gilbert et al 1994), it is found in salinity of seawater strength in both near coastal aquifers (Humphreys in press b) and in the Yilgarn (W.F. Humphreys and H.J. Hahn, unpublished 1999).

Syncarida

Of marine origin, syncarids are one of the oldest groups of freshwater fauna and the two evolutionary lines that independent invaded freshwater were the only ones to survive. The Bathynellacea probably occupied surface freshwater habitats in the Carboniferous and subsequently became restricted in living in the interstitial spaces in subterranean waters—95% of extant syncarids are strictly stygobionts (Schminke, 1986). They have limited dispersal ability and their occurrence in oligohaline and polyhaline waters is secondary (Schminke, 1981), hence their biogeography may provide useful information on past continental connections.

They became adapted to the interstitial stygofauna habitats by neoteny and the Bathynellacea now attain sexual maturity at a stage that corresponds to the zoea in the development of primitive Decapoda (Schminke, 1981).

The most primitive Bathynellacea are found in southeast Asia and of the Parabathynellidae two lines extend from there, one through Europe, Africa and South America, and the other south via Australia also to South America—along both lines the genera become more and more apomorphic in their characters (Schminke, 1974). Syncarids are considered to be rare but this is probably due to

their escaping attention by being subterranean (Schminke, 1986); indeed, recent work in the Yilgarn has found both a high diversity and large populations of syncarids in calcrete aquifers (W.F. Humphreys and H.J. Hahn, unpublished 1999). The biology of syncarids is virtually unknown.

Two new species of syncarid Crustacea (H.K. Schminke, pers. comm.), belonging to two families (Bathynellidae and Parabathynellidae) were taken sympatrically in the groundwater of the Ord River Irrigation Area. One is a species of *Atopobathynella* (Parabathynellidae). The recent finding of the genus in the arid (Barrow Island; Humphreys in press a) and monsoonal tropics of Western Australia (Ord River Irrigation Area) suggests that syncarids of the genus *Atropobathynella* may be expected throughout Australia, at least in areas not inundated by the sea during the Cretaceous (see figure in Humphreys 1999).

Ostracoda

These tiny bivalve-like Crustacea were collected from spring caves but can be expected to be more widespread. Williams (1979) reported on a collection of ostracods from 13 localities in northwestern Australia—of the 16 species collected all belonged to known genera but six were undescribed; three genera were recorded for the first time in Australia and the range of several species was extended from eastern Victoria. We can expect the subterranean fauna to be less well known (Danielopol et al. in press; P. Marmonier, pers. comm. 1999; K Wouters and K. Martens, pers. comms. 1999) as is the case for the copepods.

Copepods

These tiny Crustacea were collected from a number of piezometers and cave springs. They are being examined by Professor G.L. Pesce at University di l'Aquila, Italy. Williams (1979) also collected calanoid copepods from northwestern Australia and recorded only four species; major range extensions were made for two species of *Diaptomus* and of *Boeckella triarticulata*. Such is the poor state of knowledge of the surface fauna, but the subterranean fauna is less well known (Pesce et al. 1996a, 1996b; Pesce and De Laurentiis 1996; De Laurentiis et al. 1999; Jaume and Humphreys, in prep; D, Jaume, pers. comm. 1999).

Numbers

Of the most commonly sampled taxa, the bathynellids, mostly one or two individuals were taken except where one site was sampled repeatedly (Table 1). Hence, the intensity of sampling provides little scope for detecting diversity within the fauna at any site.

Conclusions

A significant, regionally variable, stygofauna is present in the eastern Kimberley and the neighbouring parts of the Northern Territory. A limited stygofauna inhabits both the current Ord Irrigation Area and the proposed State 2 extension. At this stage it is not known whether these fauna are the same, an uncertainty exacerbated by a natural groundwater divide between the two areas. There is a low level of confidence that the sampling has been adequate to characterise the stygofauna owing to the nature of the bores sampled, and because the bulk of the project area has not been sampled at all. The fissured and karstic aquifers adjacent to the Knox Creek Plain are potential sources of stygofauna and, as they lie outside any immediate impact of the project, could be potential buffer zones for subterranean fauna.

References

- Danielopol, D.L., Baltanás, A. and Humphreys, W.F. in press. *Danielopolina*^{ΔΔ} sp.n. (Ostracoda: Thaumatocyprididae) from a western australian anchialine cave—morphology and evolution. *Zoologica Scripta*,
- De Laurentiis, P., Pesce, G.L. and Humphreys, W.F. 1999. Copepods from ground waters of Western Australia, IV. Cyclopids from basin and craton aquifers (Crustacea: Copepoda: Cyclopidae). *Records of the Western Australia Museum* in press.
- Gilbert, J., Danielopol, D.L., and Standford, J.A. (eds). 1994. *Groundwater Ecology*. Academic Press, London.
- Humphreys, W.F., 1995. Limestone of the east Kimberley, Western Australia—karst and cave fauna. *Report to the Australian Heritage Commission and the Western Australian Heritage Committee*. 190 pp.+ xix. Unpublished.
- Humphreys, W.F., 1999. Relict stygofaunas living in sea salt, karst and calcrete habitats in arid northwestern Australian contain many ancient lineages. Pp. ^{ΔΔΔ-ΔΔΔ} in W. Ponder and D. Lunney (eds) *The Other 99%. The Conservation and Biodiversity of Invertebrates*. Transactions of the Royal Zoological Society of New South Wales, Mosman 2088.
- Humphreys, W.F., in press a. The hypogean fauna of the Cape Range peninsula and Barrow Island, north-west Australia. Pp. ^{ΔΔΔ-ΔΔΔ} in H. Wilkens, D.C. Culver and W.F. Humphreys (eds). *Ecosystems of the World, vol. 30. Subterranean Ecosystems*, Chapter 30. Elsevier, Amsterdam.
- Humphreys W F in press b Physico-chemical profile and energy fixation in an anchialine remiped habitat in north-western Australia. *Journal of the Royal Society of Western Australia*
- Jaume, D. and Humphreys, W.F. in preparation. A new genus of epactericid calanoid copepod from an anchialine sinkhole on northwestern Australia. *Journal of Crustacean Biology*
- Pesce, G.L., De Laurentiis, P. and Humphreys, W.F., 1996a. Copepods from ground waters of Western Australia. I. The genera *Metacyclops*, *Mesocyclops*, *Microcyclops* and *Apocyclops* (Crustacea Copepoda: Cyclopidae). *Records of the Western Australia Museum*, **18**: 67-76.
- Pesce, G.L., De Laurentiis P. and Humphreys W.F., 1996b. Copepods from ground waters of Western Australia. II. The genus *Halicyclops* (Crustacea Copepoda: Cyclopidae). *Records of the Western Australia Museum*, **18**: 77-85.
- Pesce, G.L. and De Laurentiis P., 1996. Copepods from ground waters of Western Australia. III. *Diacyclops humphreysi* n. sp. and comments on the *Diacyclops crassicaudis*-complex (Copepoda: Cyclopidae). *Crustaceana*, **69**: 524-531.
- Poore, G.C.B. and Humphreys, W.F., 1998. The first record of the Spelaeogriphacea Poore, G.C.B. and Humphreys, W.F., 1998. First record of Spelaeogriphacea from Australasia: a new genus and species from an aquifer in the arid Pilbara of Western Australia. *Crustaceana* 71: 721-742.
- Schminke, H.K. 1974. Mesozoic intercontinental relationships as evidenced by bathynellid Crustacea (Syncarida: Malacostraca). *Systematic Zoology* **23**: 157-164.
- Schminke, H.K. 1981. Adaptation of Bathynellacea (Crustacea, Syncarida) to life in the Interstitial (Zoea Theory). *Int. Revue ges. Hydrobiol.* **66**(4): 575-637.

Schminke, H.K. 1986. Syncarida. Pp 389-404 in L. Botosaneanu (ed.). *Stygofauna Mundi, a faunistic, distributional, and ecological synthesis of the world fauna inhabiting subterranean waters*. E.J. Brill/Dr W. Backhuys, Leiden.

Williams, W.D. 1979. Notes on the freshwater fauna of north-western Australia, especially the Kimberleys. *Records of the Western Australia Museum* 7 213-227.

Wilson, G.D.F. and Keable, S.J., 1999. A New Genus of Phreatoicidean Isopod (Crustacea) from the North Kimberley Region, Western Australia. *Zoological Journal of the Linnean Society* 126: 51-57.

Wilson, G.D.F. and Ponder, W.F. 1992. Extraordinary new subterranean Isopods (Peracarida: Crustacea) from the Kimberley Region, Western Australia. *Records of the Australian Museum* 44:279-298.

Table 2: Other aquatic fauna taken from few groundwater sampling sites.

Sampling site	Taxa
PB1	Copepoda; vermes indet.
PB2	Nematoda; Protozoa
WP10	Oligochaeta
WBS 5062	Insect larva
KNI-19	<i>Tainisopus</i> sp. (Isopoda: Flabellifera); Copepoda; Ostracoda
Siggins Spring	¹ <i>Strandesia</i> sp. (Ostracoda: Cyprididae: Cypridopsini). Genus known from Cuba (K. Wouters)[probably epigean].
HI 3/78	Nematoda
PN5D	Harpacticoidea (Copepoda).

¹ det. Prof. K. Wouters, pers. comm.

Table 1: Groundwater sites sampled by Museum of Natural Science in Western Australia (north of 16° S and east of 128° E) and the stygofauna.

Area	Bore etc.	Latitude	Longitude	Higher taxon	Family ¹	N
Kununurra	Bore west of production bores	-15.78861	128.71861	•		
Kununurra	Golf Course Bore	-15.78806	128.71472	•		
Ivanhoe Plain	HI 3/78	-15.70111	128.68972	•		
Ivanhoe Plain	medium pipe capped #82	-15.67972	128.72694	•		
Ivanhoe Plain	#83	-15.67972	128.72972	•		
Ivanhoe Plain	#84a	-15.67889	128.72861	•		
Ivanhoe Plain	PB2 & PB2M1-1	-15.67806	128.72639	Syncarida: Bathynellacea	Bathynellidae	1m
Ivanhoe Plain	PN6D	-15.64250	128.74917	Syncarida: Bathynellacea	Parabathynellidae	2
Ivanhoe Plain	PB1M1-1	-15.63278	128.74556	•		
Ivanhoe Plain	PB1	-15.63222	128.74500	Syncarida: Bathynellacea	Bathynellidae species A	5m + 32 ²
Ivanhoe Plain	PN5S	-15.62667	128.72583	•		
Ivanhoe Plain	PN5D	-15.62667	128.72583	•		
Ivanhoe Plain	VEPL shallow	-15.62028	128.75694	•		
Ivanhoe Plain	VEPL deep	-15.62028	128.75694	•		
Ivanhoe Plain	Piezo No. 30	-15.61667	128.70000	•		
Ivanhoe Plain	Boschamber deep 102/1	-15.61222	128.74278	Syncarida: Bathynellacea	Parabathynellidae	1j
Ivanhoe Plain	Boschamber shallow 102/2	-15.61222	128.74278	•		
Cave Spring Gap	CG2	-15.56667	128.76667	Syncarida: Bathynellacea		2
New piezometer		-15.54167	128.80583	•		
Cave Spring		-15.52917	128.83278	•		
Weaber Plains	WP1	-15.48861	128.82722	Syncarida: Bathynellacea		10
Weaber Plains	WP10	-15.46639	128.89111	Syncarida: Bathynellacea		2
Weaber Plains	WP6	-15.46472	128.83583	Syncarida: Bathynellacea		7
Weaber Plains	WP11	-15.45861	128.90222	Syncarida: Bathynellacea		1
Weaber Plains	WP9	-15.43917	128.91944	Syncarida: Bathynellacea		1
Ord	WBS 5062	-15.39556	128.95917	•		
Weaber Plains	WP19	-15.39417	128.95139	Syncarida: Bathynellacea		1
Ningbing Range cave	Eight Mile Well	-15.31750	128.64167	•		
	KN1-19	-15.30000	128.63000	•		
	Siggins Spring	-15.28333	128.65000	•		
	Tanmura Bore	-15.09528	128.63194	•		
	Number 8 Bore	-14.97056	128.59722	•		
	Brolga Spring Bore	-14.89750	128.56444	•		
	Limestone Well	-14.47722	128.73278	•		

¹ Determined by Prof. Dr H.K. Schminke, Universität Oldenburg, the authority on syncarids. ² Based on repeated sampling over a number of days.



APPENDIX N

CULTURAL HERITAGE PROTECTION PROCEDURES

CULTURAL HERITAGE PROTECTION PROCEDURES DURING THE FEASIBILITY STUDY OF THE ORD RIVER IRRIGATION AREA (M 2) PROJECT



Wesfarmers Limited



Marubeni Corporation

and the



Water Corporation

17 SEPTEMBER 1998

INTRODUCTION

Wesfarmers Ltd. & Marubeni Corporation, in association with the Water Corporation (the Proponents), are undertaking a Feasibility Study to establish the viability of a raw sugar industry on the Ord River Irrigation M2 Area (the Project Area), near Kununurra in the East Kimberley Region of Western Australia and the Northern Territory.

The Feasibility Study is designed to determine whether the land in the M2 Area can be developed for the purposes of irrigated farmland, the operation of processing and storage facilities related to the agricultural output from the land and the development and operation of all necessary infrastructure. Infrastructure would include, but not be limited to, roads, bridges, power supply, communications facilities, and irrigation infrastructure, the latter including water supply channels (including the M2 supply channel), secondary channels and drains, balancing storages, pump stations, flood protection levees, hillside drains, and regional ground water control systems.

The Ord River region is an area of traditional significance, occupation and use by the Miriuwung and Gajerrong Aboriginal people. The Proponents are committed to recognising and respecting Aboriginal cultural values and rights to this land. This Project offers the opportunity for the development of a mutually beneficial relationship between Aboriginal and non-Aboriginal people alike.

The *Aboriginal Land Rights (Northern Territory) Act 1976* and the *Native Title Act (1993)*, formally recognise land tenure rights of Aboriginal people in Australia. Along with this legislation, the Proponents are obliged to comply with State, Territory and Commonwealth legislation and procedures to ensure that Aboriginal cultural heritage values associated with the Project Area are adequately addressed.

This document outlines the procedures to be employed by the Proponents and observed by their employees, contractors and consultants during the Feasibility Study. Separate but complementary procedures will be established prior to the actual development of the Project.

PROTECTING CULTURAL HERITAGE

As a key component of the Feasibility Study, the Proponents will undertake a Work Programme Clearance of the land within the M2 Area to ensure that archaeological and ethnographic sites are avoided prior to any proposed ground disturbing activities. The First Stage Work Programme Clearance is scheduled to occur during September and October 1998. The Second Stage Work Programme Clearance is scheduled to occur in the 1999 dry season.

To facilitate the Work Programme Clearance, the Proponents have entered into arrangements with the Aboriginal Representative Bodies (the Kimberley Land Council, the Northern Land Council and the Aboriginal Legal Service of Western Australia) and via them the Miriuwung and Gajerrong people, to ensure that cultural heritage values and sites within the Project Area are avoided.

Aboriginal sites within the Project Area fall into two broad but not exclusive categories - archaeological sites and ethnographic sites. These are collectively known as Aboriginal sites and are protected by State, Territory and Commonwealth heritage legislation, which can impose severe penalties for knowingly or unknowingly disturbing and damaging Aboriginal sites.

CULTURAL HERITAGE VALUES

The Miriuwung and Gajerrong people have strong cultural heritage values associated with the Project Area. These values potentially include sites of mythological and ceremonial significance, occupation sites, burial sites, resource procurement sites as well as a general spiritual and emotional attachment the Miriuwung and Gajerrong people have to the land. The cultural heritage values that pertain to these Procedures apply to the following:

- All areas of land associated with the Feasibility Study of the Project Area;
- All surface archaeological and ethnographic sites, cultural materials and objects within the Project Area;
- All sub-surface archaeological materials, including human remains, which may be discovered during excavation or other earthworks during the Feasibility Study.

AVOIDANCE AND PROTECTION OF ABORIGINAL SITES

All interactions with the Miriuwung and Gajerrong people on cultural heritage issues are being managed by the Proponents Representatives. Briefings on respecting cultural heritage values will be held with the Proponent's employees, contractors and consultants prior to any ground disturbing activities in the Project Area.

All Aboriginal sites avoided as a consequence of the Work Programme Clearance, will be considered to be 'prohibited areas' in relation to any ground disturbing activities during the Feasibility Study. All known Aboriginal sites within the Project Area will be avoided at all times by the Proponent's employees, contractors and consultants. Interference with any known Aboriginal site, including visiting such sites or removing artefacts or objects, by the Proponent's employees, contractors and consultants will result in termination of their contract.

All ground disturbing activity shall be restricted to the First Stage Works, including the proposed 50 metre wide Infrastructure Corridor the subject of the Trace Survey. No access to the land within the Project Area external to the First Stage Works shall occur without the express permission of the Proponents Representatives.

All areas located during the Work Programme Clearance considered to be of Aboriginal significance as documented by a qualified archaeologist and/or an anthropologist, shall be delineated in the following manner:

- A map delineating the areas containing Aboriginal sites shall be provided to the Proponent's contractors to ensure that their work remains outside of those areas;

- Survey markers (star pickets and survey ribbon) shall be placed in close proximity to each area to ensure that contractors are aware of their locations and avoid them during ground disturbing activities as advised by the consultant archaeologist and/or anthropologist;
- A differential GPS survey of each area shall occur, in order to determine the dimensions of the area of land containing the Aboriginal site for current and future management.

Any additional areas of Aboriginal significance located within the Project Area shall be noted by the Proponents Representatives for future recording by a qualified archaeologist and/or anthropologist with the participation of the Aboriginal Representative Bodies.

PROCEDURE UPON THE ACCIDENTAL DISCOVERY OF CULTURAL HERITAGE MATERIALS DURING GROUND DISTURBING ACTIVITY

Habitation Sites

Should an archaeological site, or obvious cultural materials be located within the Project Area by the Proponent's employees, contractors and consultants or uncovered during any ground disturbing activities, the following steps shall be observed:

1. Any person making the discovery will cease the activity and notify the contractor/consultants Site Representative, who in turn shall immediately notify the Proponents Representatives;
2. The Proponents Representatives shall note the details and spatial extent of the archaeological site/cultural materials and shall advise the Site Representative accordingly. Ground disturbing activity may commence away from the archaeological site/cultural materials as advised by the Proponents Representatives;
3. The Proponents Representatives shall inform the Aboriginal Representative Bodies of the location of the archaeological site/cultural materials and shall arrange for a qualified archaeologist to record the site in detail;
4. Information on the significance of the archaeological site shall be provided to the Aboriginal Representative Bodies.

Human Remains

Should human skeletal remains be uncovered during any ground disturbing activities, then work shall immediately cease and the following action shall be taken:

1. The Proponents Representatives and the Site Representative will be notified immediately, who will in turn ensure that all access to the site is restricted. The Proponents Representatives shall immediately notify the local Police as well as the Aboriginal Representative Bodies;

2. If the remains are presumed to be human in origin, work should not continue less than 100 metres away from the remains, and only if the Proponents Representatives as well as representatives of the Aboriginal Representative Bodies are present to monitor this work;
3. The Proponents Representatives shall await advice from the Police and after consultation with the Aboriginal Representative Bodies, may arrange for a qualified archaeologist/physical anthropologist to visit the site in order to provide advice about the remains;
4. If the remains are determined as originating from a traditional burial, the Police will formally notify the Proponents Representatives. Assuming the Police agree, the site can therefore be considered to be a cultural heritage site and not a crime scene;
5. The Police will notify the appropriate State, Territory and Commonwealth agencies of the existence of the remains. The Proponents Representatives shall seek the advice of the Aboriginal Representative Bodies about what should be done with the remains. This could include leaving the remains in situ or excavation and re-burial at a location acceptable to the Aboriginal Representative Bodies.

Should the remains be in an area required for future development, the Proponents Representatives shall discuss the options for managing the remains in a manner acceptable to the Aboriginal Representative Bodies as well as the respective State, Territory and Commonwealth Government agencies.

CULTURAL PROTOCOLS

The Work Programme Clearance will involve Miriuwung and Gajerrong people, the Traditional Owners of the land within the Project Area. These Traditional Owners will be working with consultant archaeologists, anthropologists and other contractors and consultants during the Feasibility Study.

Cultural protocols need to be observed during all interactions with the Traditional Owners. While some of these protocols may not seem to be significant to non-Aboriginal people, observation of them will show respect for Aboriginal people and include:

- Not asking the names of Traditional Owners or their family members;
- Not asking about the cultural details of Aboriginal sites;
- Not taking photographs of Traditional Owners, their residences or cultural heritage sites without first asking permission;
- Not asking questions about deceased persons;
- Not insisting that male and female Traditional Owners travel together in the same vehicle; and
- Not requesting Traditional Owners to agree to or sign documents without recourse to proper advice.

Furthermore, there are general environmental protocols that also need to be observed to ensure 'best practice' and include:

- Limit vehicle use to existing roads and tracks;
- Minimise disturbance to vegetation;
- Backfill all test pits and plug all drill holes;
- Not leaving rubbish or waste behind;
- Keep all work sites clean and tidy;
- Not to use alcohol on site;
- Not to light camp fires unless absolutely necessary and not to leave fires unattended or properly extinguished;
- Leave gates and fences as they were found; and
- Avoid all stock watering points.

CONTACT DETAILS

Enquires regarding cultural heritage issues should be addressed to the Proponents Representatives:

Warren Ford (Ord Project Community Relations Officer - Wesfarmers Ltd.)

Telephone: (08) 9168 1577

Facsimile: (08) 9168 1860

Mobile: 015 984975

Or

Phil Pyle (Project Manager - Water Corporation)

Telephone: (08) 9168 0720

Facsimile: (08) 9168 0790

Mobile: 0419 902152

APPENDIX O

OUTLINE ENVIRONMENTAL MANAGEMENT PLAN

ORD IRRIGATION AREA STAGE 2 PROPOSED DEVELOPMENT OF THE M2 AREA

OUTLINE ENVIRONMENTAL MANAGEMENT PLAN

Prepared for:

**WESFARMERS LIMITED, MARUBENI
CORPORATION AND THE WATER CORPORATION
OF WESTERN AUSTRALIA**
GPO Box M978
Perth WA 6000

Prepared by:

Kinhill Pty Ltd
ACN 007 660 317
47 Burswood Road
Victoria Park WA 6100
Telephone 9362 5900, Facsimile 9362 5637

December 1999

CONTENTS

Section	Page
1 INTRODUCTION	1
1.1 Background	1
1.2 Environmental management commitments	2
1.3 Management structure, general objectives and responsibilities of the EME	2
1.4 Information sources	2
1.5 Due diligence and environmental management systems	2
2 ENVIRONMENTAL EDUCATION AND INFORMATION MANAGEMENT	4
2.1 Environmental education and training management plan	4
2.2 Legislation, policy and standards management plan	5
2.3 Records and information management plan	6
3 ABORIGINAL ISSUES	8
3.1 Native Title	8
3.2 Cultural Heritage	9
3.3 Social Impact	11
4 COMMUNITY ISSUES	13
4.1 Community Issues Management Plan	13
5 PHYSICAL ENVIRONMENTAL	16
5.1 Soil conservation, repair and restoration management plan	16
5.2 Soil chemical status	18
5.3 Surface water resources	19
5.4 Groundwater resources	23
5.5 Fire management	25
6 BIOLOGICAL ENVIRONMENT	26
6.1 Native vegetation and fauna conservation management plan	26
6.2 Revegetation and Management Plan	28
6.3 Weeds, Plant Pathogens and Pest Animals management Plan	29
6.4 Biodiversity and Nature Conservation Management Plan	31

1 Introduction

1.1 BACKGROUND

A joint venture between Wesfarmers Sugar Company Pty Ltd (Wesfarmers) and Marubeni Corporation (Marubeni) was awarded an exclusive mandate in April 1998 by the Western Australian and Northern Territory Governments to investigate the feasibility of development of a portion of Ord Stage 2 known as the M2 Development Area (the Project Area).

The proposal being considered by Wesfarmers and Marubeni involves the potential establishment of a raw-sugar industry. The industry may involve the development of farmland for the purposes of growing sugarcane, the development of a sugar mill, and the development of storage facilities at the port of Wyndham. In parallel with the feasibility study being conducted by Wesfarmers and Marubeni, the Water Corporation of Western Australia (Water Corporation) is investigating the feasibility of development of the irrigation infrastructure required to service the farmland.

Following development, the Project Area would include a raw sugar mill and approximately 32,000 hectares of land developed for farms, development of a further 3,000 hectares of land for infrastructure, and over 40,000 hectares of land managed for conservation. Farm areas would be developed on the heavy clay soils (black soils), while the land managed for conservation would include those areas that contain flora and fauna of conservation significance on the black-soil and other areas, including riparian and rocky areas, within and around the farmland.

Due to the interrelated nature of the core industry activities, Wesfarmers–Marubeni and the Water Corporation propose that an entity is established to shoulder the operational aspects of ongoing environmental management in relation to the proposed development on behalf of the industry participants. The proposed entity, or Environmental Management Entity (EME), would be owned by the industry participants, and would provide environmental management services to the owners. Key features of the proposed EME would be as follows:

- The EME would be wholly owned by the industry participants, including all three core industry participants.
- The key objective of the EME would be the management of environmental issues within the entire Project Area, on behalf of the industry participants.
- The EME would be responsible for aspects such as ongoing monitoring, analysis, and reporting on behalf of industry within the proposed development—but legal responsibility for environmental compliance would rest with the individual asset owners.

- The EME would be the focal point for community input in relation to environmental issues in relation to the proposed development.
- The EME would be resourced by the industry participants within the proposed development.

This document is the outline of the Environmental Management Plan (EMP) for the proposed development and operation of the Project Area. The EMP outline has been prepared to support the Environmental Review and Management Programme/draft Environmental Impact Statement (ERMP/draft EIS) for the Project. Finalisation of the EMP would require incorporation of any environmental conditions, operating licences for the Project, and the development of detailed monitoring and management schedules.

This document presents an indicative set of objectives and strategies that would comprise the EMP. When complete, the EMP would comprise a set of sub-plans that are described in the later chapters.

1.2 ENVIRONMENTAL MANAGEMENT COMMITMENTS

This section would consolidate the environmental management commitments made in the ERMP/draft EIS for the Project (Chapter 17 of the ERMP/draft EIS refers) and any requirements under environmental conditions, legislation or operating licences required by the Project.

1.3 MANAGEMENT STRUCTURE, GENERAL OBJECTIVES AND RESPONSIBILITIES OF THE EME

This section would outline the management structure, general objectives and responsibilities of the EME that would be established in conjunction with the Project. A description of the EME is provided in Chapter 16 of the ERMP/draft EIS.

1.4 INFORMATION SOURCES

This section would describe the information sources of reference to environmental management of the Project.

An Appendix would contain a reference list of the legislation and policy references relevant to the Project.

1.5 DUE DILIGENCE AND ENVIRONMENTAL MANAGEMENT SYSTEMS

The broad concept of due diligence is to foster (in individuals and organisations) compliance with environmental laws and to prevent environmental harm. In general, to demonstrate that "due diligence" has occurred, it would be necessary to show that a proper environmental management or control system had been implemented (to provide for compliance with environmental legislation) and that adequate supervision had been provided to ensure that the system was complied with, implemented and monitored.

Environmental due diligence requires the application of Best Practice Environmental Management (BPEM), which includes the preparation, implementation and monitoring of documents (such as an EMP), for example, through an environmental management system (EMS).

An EMS is an ideal way to demonstrate environmental due diligence and BPEM.

The concept and major components of the EMS that would be adopted for the Project are set out in the Australian/New Zealand Standard AS/NZ ISO 14000 series. The EMS therefore would have the following key components:

- organisational commitment;
- environmental policy;
- environmental aspects and impacts register;
- regulatory and legal compliance register;
- objectives and performance indicators;
- environmental management program documentation (ie. EMP);
- operational and emergency procedures;
- responsibility and reporting structure;
- training and awareness program;
- environmental performance reviews, audits, monitoring and measurement.

2 Environmental education and information management

2.1 ENVIRONMENTAL EDUCATION AND TRAINING MANAGEMENT PLAN

2.1.1 Background

It is mandatory that the EMP for the Project be followed by all personnel from the corporate and independent farms, the sugar mill and the water and drainage service provider, as well as contractors working in the Project Area.

This plan would address the environmental protection training requirements identified in the sub-plans of the EMP and the environmental induction and awareness requirements for all people involved in the Project. The plan requires the adoption of an Environmental Code of Practice (ECP) for the Project Area.

2.1.2 Risk assessment

Without adequate, up-to-date information and training, use and management of the Project Area will not achieve due diligence objectives, nor will it be cost effective.

2.1.3 Objectives

The objectives of the environmental education and training program are:

- to prevent adverse environmental impacts from construction and operations;
- to ensure all staff have relevant knowledge of environmental management, know their own (and others) environmental responsibilities and carry out their duties in order to protect the environment.

2.1.4 Management actions

The EME would:

- prepare environmental education training materials;
- prepare an ECP for construction and maintenance of the Project and obtain endorsement for the ECP from all asset owners;
- audit compliance with the ECP;

- develop and maintain an informal environmental group consisting of pro-environmental personnel (as cultural change agents) for the Project Area. The purpose of this group is to monitor and discuss environmental issues, facilitate communication of relevant environmental information, encourage environmental awareness, promote environmentally sustainable work practices, and strengthen interaction with the community;
- encourage operations and management personnel to provide suggestions for improvement in site environmental management practices;
- brief all new workers and personnel regularly deployed to the Project Area about the environmental responsibilities of the EME;
- organise and conduct regular environmental awareness-raising activities including on-site inspections/assessments, training activities, briefing sessions and preparation of information bulletins.

2.2 LEGISLATION, POLICY AND STANDARDS MANAGEMENT PLAN

2.2.1 Background

It is mandatory that all activities conducted in the Project Area comply with relevant State, Territory and Commonwealth Laws.

2.2.2 Risk assessment

If the EME does not identify all relevant legislation, policies and standards then Project related activities may not be compliant with these and legal proceedings may result.

2.2.3 Objectives

The objective of legislation and standards management will be to comply with all relevant government legislative requirements and Australian/International Standards.

2.2.4 Management actions

The EME would:

- consult adequately with all relevant levels of government in order to obtain all legislative and policy decisions relevant to the Project;
- obtain a copy of all relevant legislation and develop and update a legislative/policy register by placing a request, as a standing order notification, for copies of all new legislation and policies;
- obtain copies of all relevant Australian standards.

2.3 RECORDS AND INFORMATION MANAGEMENT PLAN

2.3.1 Background

Acquisition of information through monitoring, review and research will be an ongoing process, and an accurate, diverse and relevant information base will be essential for understanding and managing the environment. Reporting the results of monitoring and performance reviews and recording the changes in environmental conditions are particularly important if the EMP is to be useful, and provide a due diligence role. Records and information must be readily accessible and interpreted to assist planning of site activities, construction, and maintenance programs and to enable cost-effective, informed environmental management practices to be undertaken.

2.3.2 Risk assessment

Without appropriate records, performance reviews and assessments, it will not be able to demonstrate to outside agencies an adequate base for decision making and environmental due diligence.

2.3.3 Objectives

The objectives of records and information management will be to:

- obtain and maintain information pertinent to operation, construction and environmental management of the Project Area;
- use records and information to facilitate safe and sustainable development and environmental management in the Project Area;
- initiate and maintain a land use database and information for operations in the Project Area.

2.3.4 Management actions

The EME would:

- develop an appropriate filing or reference system for all information, databases, records, and references about all issues relevant to work activities and management of the Project Area;
- prepare an index of this material, update it annually and distribute it to relevant authorities;
- progressively incorporate baseline information and monitoring data into a computerised environmental management system;
- report the results and interpretation of the monitoring process on an annual basis on behalf of the industry participants. The annual report would detail actual environmental performance against the environmental performance targets detailed in the EMP, and would be made readily available to the industry participants. The

annual report would also be made available to relevant agencies and possibly other organisations and community interest groups.

3 Aboriginal Issues

3.1 NATIVE TITLE

3.1.1 Background

The land encompassing the Ord and Keep rivers, including the Project Area, is of traditional and current significance to the Miriuwung and Gajerrong people.

The early development of the ORIA Scheme occurred at a time when Aboriginal people were not consulted. In recent years, Aboriginal people have actively sought to have their traditional rights recognised, and to participate and share in the benefits of economic development.

The Miriuwung and Gajerrong people lodged three Native title claims under the *Native Title Act 1994*, over a significant portion of the East Kimberley in Western Australia and the Northern Territory in 1994 and 1995. These claims cover the entire Project Area.

In 1997, the Northern Land Council also lodged a land rights claim under the *Aboriginal Land Rights (Northern Territory) Act 1976* over the portion of the Project Area located within the Spirit Hills pastoral lease.

In 1998, the Federal Court of Australia determined that Miriuwung and Gajerrong people hold native title rights to an area of land the subject of the first of the three native title claims. This determination covers approximately 7,900 square kilometres and includes the Ord River, Lake Argyle and approximately 100 square kilometres of the Project Area.

For land that is the subject of a native title determination and land that is the subject of a native title claim, the native title holders and claimants may voluntarily surrender their native title rights and interests by way of a negotiated settlement. Such a negotiated settlement is known as an Indigenous Land Use Agreement (ILUA). Mutually agreed benefits packages for the native title holders and claimants are a key element of any ILUA, in return for the voluntary surrender of native title rights and interests over the land, enabling the development to proceed.

Wesfarmers-Marubeni and the Water Corporation intend to negotiate the terms of an ILUA with the Miriuwung and Gajerrong people prior to the start of Project construction.

3.1.2 Risk Assessment

If the EME does not support those elements of the ILUA directly relevant to the environmental management of the Project Area, then the good faith established with the Miriuwung and Gajerrong people may be compromised.

3.1.3 Objectives

The objective of supporting the terms of the ILUA would be to ensure that the good relationship with the Miriuwung and Gajerrong people is maintained for the life of the Project, benefiting the corporate farmers and independent farmers alike.

This objective would be met by ensuring that ongoing strategies for the delivery of the commitments made in the ILUA including farm and enterprise management support and opportunities, suitable employment opportunities including environmental monitoring, and access to the conservation area occur.

3.1.4 Management Actions

The EME would undertake the following actions with the Miriuwung and Gajerrong native title holders and claimants with regard to the Project Area:

- have ongoing transparent interaction with the native title holders/claimants as defined in the Community Consultative Plan (see Community Issues);
- establish an ILUA Implementation Plan to ensure that any outstanding commitments that are attributable to the EME are honored;
- ensure that native title holders/claimants have uninterrupted access to the conservation area to enable them to observe their native title rights and interests.

3.2 CULTURAL HERITAGE

3.2.1 Background

There are a number of significant cultural heritage sites within and in close proximity to the Project Area. These cultural heritage sites are protected by State, Territory and Commonwealth heritage legislation. Many of these sites are of cultural significance to the Miriuwung and Gajerrong people. One such site was listed on the Register of the National Estate in 1980 because of its significant cultural heritage values and is known as the Weaber Range Sites Complex.

The Miriuwung and Gajerrong people have participated in a cultural heritage assessment of the Keep River Plain and the Northern Territory portion of the Knox Creek Plain. The locations of cultural heritage sites have been documented accordingly. A limited cultural heritage assessment of the Weaber Plain and the Western Australian portion of the Knox Creek Plain has occurred to date.

The sites that may occur in the region include places of mythological and ceremonial significance, middens, fish traps, stone arrangements, rock-shelters, hearths, grinding hollows, paintings, engravings, burials, isolated artefacts, artefact scatters, stone

quarries, ochre quarries and scarred trees. The Project Area has no known places of non-Aboriginal historic heritage value.

Most of the proposed development of the Project Area is restricted to the black soil plains. However, it may be necessary to source road pavement material sites off the black soil. The topography of the area has played a role in protecting sensitive natural areas and cultural heritage sites. A large number of cultural heritage sites, in particular rock art sites and rock-shelters occur within the adjacent ranges, and within valleys where they are sheltered from direct impacts. Most cultural heritage sites will escape direct impact from the proposed development, however, secondary impacts from visitation may occur.

Major gaps in information relating to cultural heritage sites within the Project Area relate to the:

- lack of available information from Government agencies;
- inaccuracy of information, particularly location and spatial information;
- lack of significance information;
- sensitivity mapping;
- cultural landscapes.

A predictive model developed for the likely distribution of archaeological sites within the black soil plains has been tested during recent archaeological assessments. However, a further archaeological assessment of the black soil plains, particularly the portion of the Weaber Plain that is located in the Western Australian portion of the Project Area remains to be undertaken. This information is considered important for the long-term integrated management of the Project Area and to assist the EME setting management objectives and actions for the documentation and protection of cultural heritage sites within the conservation area.

Expectations of the EME regarding management of the cultural heritage values of the Project Area should be consistent with what is expected of other agencies with similar responsibilities.

There are no historic heritage sites of non-Aboriginal value known for the Project Area, hence no management plan is required. However, if any area or object potentially of significance is located, the EME would contact the relevant Government agency.

3.2.2 Risk Assessment

If a cultural heritage site is degraded by the development of the Project Area or subsequent operations, legal proceedings may result.

3.2.3 Objectives

EME objectives would be to:

- establish a Cultural Heritage Management Plan co-operatively and jointly with the Miriuwung and Gajerrong people;

- comply with State, Territory and Commonwealth cultural heritage legislation for the protection of the cultural heritage values of the land within the Project Area;
- comply with Miriuwung and Gajerrong aspirations for the protection of cultural heritage values of significance to them;
- prohibit/minimise the effects of construction, maintenance and farming activities on cultural heritage sites;
- raise awareness among employees, contractors and future landowners and operators on the importance of the cultural heritage values of the Project Area.

3.2.4 Management Actions

The EME would:

- establish a working relationship with the Miriuwung and Gajerrong people and have consistent, open and honest consultation;
- hold regular meetings with the Miriuwung and Gajerrong people about any proposals that may impact the cultural heritage values of the Project Area, prior to any action being undertaken;
- comply with relevant cultural heritage legislation;
- implement the Cultural Heritage Protection Procedures during the construction and operation phase of the Project;
- undertake detailed recording of cultural heritage sites within the Project Area;
- provide appropriate information to the appropriate Government agency on the location and significance of cultural heritage sites;
- compile, manage and update the cultural heritage data base for the Project Area on a regular basis;
- undertake management activities on cultural heritage sites (signage, fencing) as required.

3.3 SOCIAL IMPACT

3.3.1 Background

In 1978, the Commonwealth and Western Australian Governments jointly undertook a review of the ORIA Stage 1, and examined the impact of the development on Aboriginal people. The review noted that the development had *‘contributed to the dislocation of the life and religion of Aboriginal people living in the area by destroying land of sacred and traditional value’*.

The review found that Aboriginal people residing in Kununurra were experiencing acute social problems, some of which stemmed from the development of ORIA Stage 1. These social problems included the lifestyle changes that occurred as a result of the flooding of Lake Argyle, the displacement of Aboriginal people from the

pastoral stations, the loss of access to country and loss of sacred sites caused by the inundation of Lake Argyle and the development of ORIA Stage 1.

Wesfarmers–Marubeni and the Water Corporation intend to negotiate the terms of an ILUA with the Miriung and Gajerrong people. The ILUA would offset any potential negative social impacts on Aboriginal people, which would be identified during the proposed Aboriginal Socio-Economic Impact Assessment (ASEIA).

An Aboriginal Employment Skills Audit would be established to specifically target the Aboriginal community in order to ensure that there is an understanding of the employment skills within Kununurra and Wyndham prior to project construction.

3.3.2 Risk Assessment

If the EME does not establish mechanisms for ensuring that potentially negative social impacts on Aboriginal people (particularly Miriung and Gajerrong) are addressed during the construction and operation of the Project, then it is possible that the EME will not be supported by the Aboriginal community, resulting in opposition to the Project.

3.3.3 Objectives

EME objectives will be to:

- minimise any negative socio-economic impacts and maximise any positive impacts of the proposed development on the Miriung and Gajerrong people;
- ensure that there is ongoing consultation;
- ensure that there are ongoing meaningful employment opportunities;
- provide the opportunity for construction/operational personnel to be made aware of cross cultural issues.

3.3.4 Management Actions

The EME would:

- ensure that any commitments identified and agreed during the ASEIA are fulfilled;
- explore the opportunity for representation from the Miriung and Gajerrong community on the EME;
- ensure the Community Consultative Plan includes mechanisms for active consultation with the Miriung and Gajerrong community;
- ensure that the Aboriginal Employment Skills Audit is updated on a regular basis, and ensure that there are identified ongoing opportunities for the meaningful employment of Aboriginal people;
- establish and enforce a compulsory cross cultural awareness course for all construction/operational personnel to be facilitated by the Miriung and Gajerrong people.

4 Community Issues

4.1 COMMUNITY ISSUES MANAGEMENT PLAN

4.1.1 Background

The nearest population centres to the Project Area are the towns of Kununurra and Wyndham. Both towns are in the Shire of Wyndham-East Kimberley. Aboriginal people comprise about 34% of the total population of the Shire.

The pastoral industry and irrigated agricultural operations are the two major activities contributing to agricultural production in the region. Tourism has become a major industry generally in the Kimberley.

The estimated direct workforce required for the development of the Project Area would be approximately 550 full-time equivalent positions. This estimate includes employment on the corporate and independent farms, in the sugar mill, in harvest and transport operations, in water supply operations, in environmental management, and in general management and administration.

The estimated indirect workforce would be seventy-five people and an induced workforce of 200. Indirect employment refers to jobs in businesses supplying goods and services to the agricultural sector. Induced employment refers to jobs created by the personal consumption and associated activities of people employed directly and indirectly in the agricultural sector.

It is anticipated that the numbers of construction personnel would range from 250-650 per annum over a three-year period. Whilst many construction workers would be sourced locally, it is anticipated that the majority would originate from outside the Kimberley region, and would be accommodated in a self-contained construction camp in the Project Area. The construction camp would initially accommodate approximately 650 construction workers. At the completion of construction, the camp may be reconfigured as 200 single accommodation units to house seasonal workers. The social impact of the construction workforce on the people and facilities of Kununurra and Wyndham is expected to be minimal.

The estimates of net population increase in Kununurra range from 1,397 persons to 1,954 persons. The Ministry for Planning is in the final stages of the preparation of the Kununurra-Wyndham Area Development Strategy (KWADS). This strategy is intended to provide direction for the long-term use and management of land in the area, as well as promoting the coordination of activities and initiatives of the community, private enterprise and Government. The KWADS should provide a sound

basis for Government to plan the long-term provision of services in the area, including any significant expansion of Kununurra.

There may be a need for between 500 and 700 new dwellings to be constructed in Kununurra as a result of the proposed development. Plans to increase the number of beds in the Kununurra Hospital to accommodate any increase in demands for hospital services from anticipated growth have been factored in.

Kununurra has two schools: Kununurra District High School and St. Joseph's Catholic School. Currently there is no senior high school in either Kununurra or Wyndham. The anticipated population growth and projected increase in enrolments may necessitate development of another combined pre-school and primary school, and may precipitate an upgrade of the Kununurra District High School to a senior high school.

The maintenance of access to local waterways for both recreational and lifestyle purposes is an important issue for the local community. The Project has been designed in such a way that access to the Keep River would be maintained.

Significant community consultation has been undertaken in relation to the proposed development throughout 1998-99. These consultation activities have included the use of a range of media outlets, brochures, public displays and meetings, and direct consultations.

4.1.2 Risk Assessment

If the EME does not establish mechanisms for ongoing and transparent community interaction with the Kununurra and Wyndham community, then the integrity of the EME from the perspective of the local community may decline and may lead to a negative community perception of the Project.

4.1.3 Objectives

The objective of community interaction management will be to minimise deleterious socio-economic impacts on the surrounding area, including all neighbouring landholders, and encourage effective and positive communication and community liaison between the EME, project asset owners and external groups and agencies.

These objectives will be met by the establishment of four sub-Plans which are as follows:

- the Code of Conduct Plan. The objective of the Plan is to establish a code of conduct for employees of the construction contractors, with respect to their interaction with the Kununurra and Wyndham communities. This Plan would be enforceable through construction contracts;
- the Community Consultative Plan. The objective of the Plan is to establish meaningful and transparent consultative mechanisms with the Kununurra and Wyndham community;
- the Recreation and Tourism Management Plan. The objective of the Plan is to minimise disruptions to traffic, recreation and tourism and, where practicable, to allow for enhanced recreation and tourism (as supplementary land use) of the Project Area;

- the Security Management Plan. The objective of the Plan will be to prohibit unauthorised access to the Project Area facilities and to control access to the conservation area.

4.1.4 Management Actions

The EME would:

- have ongoing transparent interaction with the community in the form of meetings, visits to the Project Area and the production of a regular newsletter;
- establish a Code of Conduct Plan;
- establish a Community Consultative Plan;
- establish a Recreation and Tourism Management Plan;
- establish a Security Management Plan;
- establish a Visitors Centre at the Sugar Mill to inform the community about Project activities, and to act as the focal point for the operations of the EME;
- establish and maintain recreation areas within the Conservation Reserve associated with the Lower Keep River;
- erect suitable information signs;
- accommodate and contribute to community requests and activities on an as needs basis.

5 Physical environment

5.1 SOIL CONSERVATION, REPAIR AND RESTORATION MANAGEMENT PLAN

5.1.1 Background

Soil erosion, especially accelerated erosion, may be a significant management issue in the Project Area. The soils of the Project Area are generally moderately erodible and may become highly erodible when disturbed. Likely causes of accelerated erosion are:

- vehicular movement;
- indiscriminate crossing of watercourses;
- frequent burning of the vegetation;
- construction activities;
- old quarries.

Repair, restoration and rehabilitation may be required following any construction activities that have removed vegetation cover and exposed the soil. These measures will also be required to effect stabilisation and recovery of eroded areas currently present. Passive and active (assisted) rehabilitation strategies would be required. Repair of damage would be a particularly important factor in reducing land degradation, minimising soil erosion, allowing regeneration of vegetative cover and retaining the long-term viability of irrigated agriculture in the Project Area.

5.1.2 Risk assessment

If Project activities are to avoid environmental degradation and reclamation activities and comply with legislative requirements, then appropriate soil conservation controls would have to be established and implemented.

5.1.3 Objectives

The objectives of soil erosion management would be to:

- minimise disturbance and impacts to soils outside of farm areas;
- stabilise disturbed areas against the erosive force of water;
- restore, as nearly as practicable, the original productivity of eroded areas.

5.1.4 Management actions

Wesfarmers–Marubeni, the Water Corporation and independent farmers, under the auspices of the EME, would ensure soil erosion in the Project Area would be controlled by a combination of the following management strategies:

- controlling drainage by providing levee banks to prevent floodwaters entering the developed area;
- grading land on farms to gentle slopes to minimise stormwater runoff velocities;
- sizing and designing receiving drains to accommodate anticipated flow regimes;
- providing buffer zones on both sides of watercourses to allow riparian vegetation to continue to stabilise soils in these areas;
- rehabilitating disturbed areas as soon as possible following disturbance during construction;
- formulating and implementing appropriate rehabilitation plans and programmes including topsoil stripping and stockpiling, land preparation, and reseedling to facilitate regeneration of disturbed areas;
- managing crops in such a way that crop cover of the soil is maximised, particularly during the wet season when erosive rainfall events may occur.

Drainage waters leaving farms would first pass through farm drains and tailwater return systems that would settle and collect larger soil particles, such as coarse silts and sands. Farm maintenance would include regular desilting of these drains.

Management of sediment during construction would involve a combination of the following measures:

- wherever practicable, restricting ground-disturbing operations to the dry season;
- restricting ground-disturbing operations to the minimum area required to facilitate construction;
- collecting and storing for future use any topsoil from areas to be disturbed;
- installing and maintaining temporary sediment traps downstream of any areas to be disturbed;
- progressive clearing, developing and rehabilitating, wherever possible using locally won topsoil, of any areas that are no longer going to be disturbed.

Localised areas of high water velocity may occur at structures constructed across natural watercourses, such as the siphon and bridge crossings of Knox Creek and the Keep River. Appropriate erosion protection measures such as stone pitching and bridge abutments would be developed for these areas as part of the detailed design of the Project.

The EME would:

- monitor erosion along all water courses within and downstream of the Project Area, including constructed drains at the completion of each wet season and undertake the erosion protection measures on an as-needed basis;

- brief all contractors involved in construction activities on the precautions and measures necessary to avoid significant erosion impacts. All contractors would be required to formally acknowledge having received and understood the briefing, and agree to abide by the requirements by signing the Environmental Code of Practice;
- assess all construction activities using photographs, maps, ground truthing and reporting;
- audit construction activities to ensure that vegetation clearing is minimised and is at a level consistent with:
 - design needs for operations, construction and maintenance requirements;
 - requirements for bushfire control (e.g. required fire breaks);
 - preservation of conservation zones (No Go areas);
 - the maintenance of areas containing significant conservation values.
- ensure that areas being rehabilitated and revegetated are fenced or similarly protected to minimise disturbance and that the locations of such areas are shown on maps;
- develop a revegetation monitoring program to assess the success and progress of restoration procedures. This program should allow for at least one visit every three months. Monitoring procedures to be adopted will include fixed photopoints, with photographs to be taken before commencement of the revegetation program and biannually.

5.2 SOIL CHEMICAL STATUS

5.2.1 Background

The application of water and fertiliser may impact on the natural physical and chemical status of the soil. Such impacts may include:

- increased levels of salt and sodium ions (sodicity) specifically associated with irrigation;
- an increase in soil-available-nutrient status resulting from the application of fertiliser and from natural nitrogen fixation from leguminous crops;
- long-term changes in the overall balance of macro- and micronutrients in the soil reflecting the cropping and fertiliser regimes.

A review carried out in ORIA Stage One by Lavelle (1983) concluded that salinity and sodicity were not a problem at that time. However, Lavelle noted a high relative bicarbonate concentration (110 mg/L) in the irrigation water and preferential precipitation of calcium on to the soil and release of sodium. This created a potential hazard to irrigation, particularly for the cracking clays, which have a high susceptibility to sodium damage.

5.2.2 Risk assessment

Without monitoring of changes in soil chemical status, and changes in management practices as necessary, soils within the Project Area have the potential to suffer from sodium damage or salinity. As such the sustainability of irrigated agriculture may be affected or remedial measures required.

5.2.3 Objectives

The objective for managing soil chemical status would be to ensure long term sustainability of irrigated agriculture by avoiding subsoil salinity and sodium damage.

5.2.4 Management activities

The EME would:

- conduct long term monitoring of soil chemical status in the Project Area, including:
 - sodium adsorption ratio;
 - exchangeable sodium percentage (ESP);
 - electrical conductivity;
 - salinity;
 - macro-and micronutrient status;
 - organic matter content;
 - pH;
- maintain records of the monitoring results so that long term trends can be assessed;
- undertake research into the relationship between farm management practices and soil chemical status;
- provide advice to farmers on measures to manage soil chemical status, based upon the results of monitoring and research.

5.3 SURFACE WATER RESOURCES

5.3.1 Background

As with ORIA Stage One, releases of water from Lake Argyle, flowing via Lake Kununurra would be the source of irrigation water for the Project. The distribution of water from Lake Kununurra to the Project Area would be via the purpose-built M2 Channel.

The Keep River, located between the Ord and Victoria river catchments, is the most significant watercourse draining the Project Area. In addition to the Keep River, Sandy Creek drains the easternmost fringes of the Keep River Plain. The entire Project Area would be contained within the lower reaches of the Keep River and Sandy Creek catchments. Both the Keep River and Sandy Creek discharge into Joseph Bonaparte Gulf.

Nearly all rivers and streams in the region flow only in the wet season. Permanent water is therefore restricted to sheltered pools and billabongs that retain water during the dry season, and the tidal reaches near the river mouths. Pools and springs are important refuge areas for fauna in an otherwise seasonally dry environment.

5.3.2 Risk assessment

There is the potential for increased sedimentation and contamination of water resources downstream of the Project Area. Wesfarmers–Marubeni, the Water Corporation and independent farmers, under the auspices of the EME, would have a responsibility to ensure that water quality target levels, such as the ANZECC Guidelines, are not exceeded. In order to provide for due diligence information about the effects of Project activities, a monitoring program would be necessary. Organisations and/or individuals would be liable for prosecution if statutory guidelines for water quality were exceeded due to Project activities.

5.3.3 Objectives

The objectives for managing surface water resources would be to:

- conserve water resources consistent with best practice construction and farming requirements;
- ensure that water quality is not diminished as a result of activities;
- conserve natural water supplies, particularly biological water flows and dry-season water sources, that are of significance to biological communities.

5.3.4 Management actions

Wesfarmers–Marubeni and independent farmers will:

- develop all farms in the Project Area with irrigation tailwater management systems. Each tailwater management system would consist of the following elements:
 - tailwater ditches that collect tailwater from the furrows and deliver it to a tailwater dam;
 - tailwater dams. The volume of these dams would be optimised during detail design with the objective being to virtually eliminate discharges of irrigation tailwater during the dry season. As a minimum, the volume of the tailwater dam would be sufficient to provide the specified first-flush stormwater retention capacity for the Project—12 mm of rainfall runoff for sugarcane farms and 25 mm of rainfall runoff for all farms using endosulfan or any other chemicals perceived to be of high risk to the aquatic environment;
 - tailwater return pumps and pipelines that would return irrigation tailwater to the farm head ditch or to other intermediate points in the farm irrigation system for application to the crop. The tailwater return pumps would be set to operate at partial filling of the dam, thereby reducing the volume of tailwater requiring storage;
- adopt measures to minimise the effects of chemical spray drift, including:

- adoption, where appropriate, of the integrated pest management strategy developed by AGWEST for ORIA Stage One to minimise the amount of pesticides used;
- strict control on the use of pesticides, including mandatory adoption by all farmers of the spray calendar developed annually for ORIA Stage One;
- minimisation of the use of aerial spraying, by using tractor-based spraying to the maximum extent possible;
- avoidance of unsuitable weather conditions such as surface temperature inversions and unstable conditions during aerial spraying whenever possible;
- utilisation of a large droplet size during aerial spraying;
- a requirement that all commercial spray operators be accredited to a national registration programme;
- management measures be adopted for the Project to minimise the effects of airborne dust;
- provision of dedicated on-farm access tracks that would not have agricultural chemicals applied to them;
- wherever possible, adoption of ‘minimum tillage’ farming practices.
- obtain approval from the EME for all intended applications of endosulfan;
- maintain the capacity of the first-flush basins through regular inspection and removal of silt;
- only apply fertilisers or chemicals to crops when the first-flush basin capacity is available;
- maintain registers of all chemicals and fertilisers used on the farms with the minimum data to include:
 - trade name and active constituents;
 - timing of application (dates);
 - mode of application;
 - area of application (farm blocks);
 - application rate;
 - meteorological conditions at time of application.
- provide the completed registers of chemical and fertiliser use to the EME on an annual basis.

The Water Corporation would:

- control aquatic weeds in the irrigation channels and balancing storage dams by a combination of mechanical weed removal and/or periodic dosing with a chemical such as acrolein. Chemical dosing would be in accordance with best-practice procedures as follows:

- emptying the channel, locking offtakes, erecting warning signage and notifying farmers prior to injection of the chemical;
- releasing a known flow of water to obtain a water depth of approximately 0.5 m into the channel and releasing the chemical from a controllable release point to maintain an initial concentration of 15 ppm (in the case of acrolein);
- releasing a marker dye to denote the chemical front;
- shutting flow to the channel and holding the chemical in the channel for a minimum of forty-eight hours before diluting by release of additional water and use of the water for irrigation.
- maintain a register of chemical use in the Project Area, with the minimum data to include:
 - trade name and active constituent;
 - timing of application (dates);
 - mode of application;
 - location of application;
 - application rate;
 - meteorological conditions of time of application.
- provide the completed register of chemical use to the EME on an annual basis.

The EME would:

- initiate and undertake regular monitoring of water quality at strategic locations upstream, within and downstream of the Project Area. The monitoring programme would concentrate on establishing a baseline by collecting data on specific parameters associated with activities in the Project Area. The sampling regime would include:
 - monthly samples of irrigation water;
 - annual samples of soil from representative farm blocks;
 - annual samples (water and sediment) from all tailwater return systems;
 - monthly samples from all drains;
 - monthly samples for all receiving waters, including locations upstream of the Project Area;
 - monthly samples of groundwater discharges.
- have all samples analysed by NATA registered laboratories, utilising standard methods of analysis;
- establish and maintain a database of water quality monitoring data and relevant ANZECC criteria;
- provide advice to Wesfarmers–Marubeni, the Water Corporation and independent farmers on management practices to minimise impacts of Project activities on surface water resources.

5.4 GROUNDWATER RESOURCES

5.4.1 Background

Development of the Project Area for broad-acre flood irrigation is expected to result in an increased rate of water infiltration (known as accessions) to underlying aquifers and a consequential rise in groundwater levels.

The rate of groundwater rise and the need for groundwater management measures would be influenced by a number of factors, including the magnitude of the accessions to groundwater, the initial depth of groundwater from the surface, and local hydrogeological features. Agricultural activities are generally not affected unless groundwater levels are within approximately 2 m of the surface, a condition referred to as waterlogging. However, management measures are generally required for groundwater within 5 m of the surface, particularly if the groundwater is saline or the rate of groundwater rise has the potential to cause waterlogging in a short timeframe.

5.4.2 Risk assessment

Without proactive management, groundwater levels in some locations within the Project Area would rise to an extent that irrigated agriculture may be adversely affected.

5.4.3 Objectives

The objectives of managing groundwater resources would be to:

- ensure groundwater quality is not unnecessarily diminished as a result of farming activities;
- conserve groundwater resources that are of significance to biological communities;
- protect off-farm areas from groundwater impacts.

5.4.4 Management activities

Wesfarmers–Marubeni and the Water Corporation under the auspices of the EME would:

- undertake drilling across the interpreted position of the paleochannel aquifers in order to define their actual position beneath the irrigation area;
- install an extensive network of groundwater monitoring bores within and adjacent to the irrigation area prior to the commencement of irrigation. This network would include bore transects aligned perpendicular to the Keep River and Sandy Creek to acquire additional data for the better understanding of the river–groundwater interactions, and the establishment of monitoring bores adjacent to Milligan Lagoon;
- analyse samples of groundwater, collected during the above drilling, to quantify the vertical and horizontal water quality distribution;

- install test dewatering bores and test them to confirm aquifer yields and response of the aquifers to pumping;
- update the existing groundwater model for the Project Area, based upon data collected from the drilling programmes, and make the model available to the EME.

The Water Corporation would:

- adopt engineering design standards that comply with current best practice for all irrigation channels and regulating storages intended to convey or store water for prolonged periods. These design standards would specify the minimum thickness and compaction levels of the clay lining systems provided to minimise accessions to groundwater;
- site regulating storages in areas that naturally contain greater surface thickness of the less permeable Aquitaine clays;
- design drains for stormwater runoff with broad channel inverts to minimise excavation, thereby containing the channel inverts where possible in the naturally occurring less permeable surface soils;
- adopt comprehensive supervision and quality assurance procedures to ensure that the design intent is fulfilled during construction;
- develop and maintain a register of irrigation water supplied to each farm unit and make this register available to the EME on an annual basis.

Wesfarmers–Marubeni and independent farmers would:

- develop precision farm water management techniques, based upon the measurement of actual crop water use in the soil profile;
- use the above techniques to determine the timing and magnitude of irrigation applications.

The EME would:

- undertake annual monitoring of groundwater levels from all monitoring bores in the Project Area;
- undertake annual collection of groundwater samples and have these analysed at a NATA registered laboratory, using standard methods of analysis, for:
 - salinity (TDS);
 - nutrients;
 - insecticides and herbicides used in the Project Area.
- establish and maintain a data base of groundwater levels and groundwater quality analyses;
- regularly update the groundwater model;
- initiate and manage the timely installation of groundwater recovery bores, sub-soil drains and collector pipelines in the Project Area.

5.5 FIRE MANAGEMENT

5.5.1 Background

Typically, much of northern Australia has and continues to be burnt during the dry season, resulting in changes to the structure and composition of indigenous vegetation communities and an increased incidence of weeds.

5.5.2 Risk assessment

Inappropriate fire management can lead to the loss of life and property as well as reduce the conservation values of conservation areas.

5.5.3 Objectives

Objectives of fire management would be to:

- conform to all statutory requirements;
- prevent damage to human life and property;
- reduce the frequency, extent and intensity of wildfires;
- minimise the risk of fires entering or spreading beyond the Project Area or into the Project Area;
- protect any species and habitats sensitive to fire or inappropriate fire regimes, especially monsoon forest areas;
- maintain existing plant and animal communities.

5.5.4 Management activities

The EME would:

- prepare a Fire Management Plan for the Project Area following the receipt of advice from CALM and the Parks and Wildlife Commission;
- apply for membership of the Bushfires Council (Northern Territory);
- co-ordinate and provide training in the operation of the Fire Management Plan.

6 Biological Environment

This chapter provides the EMP sub-plans for each of the following topics:

- native vegetation and fauna conservation;
- revegetation;
- weeds, plant pathogens and pest animals;
- biodiversity and nature conservation.

The sub-plans would form an integrated management strategy for the biological environment of the Project Area.

6.1 NATIVE VEGETATION AND FAUNA CONSERVATION MANAGEMENT PLAN

6.1.1 Background

The issues considered in this sub-plan are plant and animal species, communities, habitats and therefore, some aspects of biodiversity. An important feature of the Native Flora and Fauna Management Plan would be to manage and conserve listed ecologically significant communities and the majority of all vegetation communities.

Wesfarmers–Marubeni and the Water Corporation are committed to preserving the ecological and biodiversity values of the Project Area consistent with the proposed construction, farming and maintenance activities. Disturbance to the indigenous plant communities surrounding the farm areas would be minimised during construction and after development. Preventing the introduction and spread of declared and environmental weeds, pest animal species and plant pathogens is of importance to this plan.

6.1.2 Risk assessment

Land management and operations in the Project area should not be allowed to jeopardise vegetation and fauna values in the conservation areas. In particular, degradation of vegetation in the conservation areas would result in public embarrassment if these areas are no longer suitable for their intended purpose and therefore require restoration and/or rehabilitation by the EME; and pressure for the conservation area to be managed by government agencies.

6.1.3 Objectives

Objectives for the management of native flora and fauna would be to:

- identify, protect and maintain flora and fauna species, vegetation communities and habitats;
- maintain and not degrade the ecological integrity and biodiversity of the conservation areas;
- rehabilitate areas disturbed during construction, enhance native flora, vegetation communities and habitats.

6.1.4 Management actions

Wesfarmers–Marubeni and the Water Corporation would:

- undertake a detailed biological survey of the conservation area;
- preserve vegetation communities consistent with construction, farming and maintenance requirements by establishing dedicated conservation area as described in the ERMP/DRAFT EIS;
- ensure if there is any loss in the use of flora and fauna and other resources by the Miriuwung and Gajerrong people that it would be addressed in an Indigenous Land Agreement between the co-proponents and the Miriuwung Gajerrong people;
- protect the conservation area from construction impacts by clearly marking its location on maps and on the ground;
- minimise the possibility of weed invasion and the risk of introduction and establishment of new weed species and plant pathogens during construction by requiring construction contracts to include provisions outlined in the Weed Management Plan (Section 6.3).

The EME would:

- protect areas containing plant species of particular conservation significance by controlling access through signage, fencing and the development of walk trails;
- undertake rehabilitation of borrow pits and other sites not intended for farms using flora species endemic to that area and the most appropriate methods (e.g. topsoil and vegetation spreading, direct seeding and seedlings);
- establish, maintain and upgrade maps, diagrams, plans and photographs to indicate ecologically significant areas;
- take photographic records of each of the flora and fauna monitoring sites to illustrate any long term changes in the vegetation;
- establish permanent monitoring sites for flora in the conservation area along selected corridors. In the conservation area at least three, 20m x 20 m permanent quadrats would be established in each of the different vegetation associations;
- establish transects to monitor condition where the vegetation varies rapidly as on the river and creek banks and wetlands;
- develop terrestrial fauna assessment sites for frog call census; pitfall lines and elliott traps; spotlighting transects; bat trapping; timed counts; records of nesting and box trap;

- develop aquatic fauna assessment sites for sampling by gill nets, fine mesh seine, scoop nets and beam trawl nets in the estuarine portions of the Keep River and Sandy Creek.

6.2 REVEGETATION AND MANAGEMENT PLAN

6.2.1 Background

This section covers the requirements for rehabilitation of areas, especially along drainage channels.

The key management issues are:

- restoration of areas damaged during construction;
- fire management, particularly the intensity, optimal season, length between fires and percentage of area burned;
- weed control, including along water courses, roads, boundaries with farms;
- use of seed from native plant species collected before the vegetation is cleared for revegetation;
- protection of threatened flora and fauna;
- ongoing surveying to monitor the success of the different rehabilitation methods and seed mixes used.

6.2.2 Risk Assessment

Wesfarmers–Marubeni and the Water Corporation are committed to undertake appropriate rehabilitation of areas degraded as a result of development. If Project activities are to avoid environmental degradation and expensive rehabilitation activities, and comply with legislature requirements, the appropriate revegetation of disturbed areas must be implemented.

6.2.3 Objectives

The objectives of rehabilitation management are to:

- protect and enhance indigenous species and communities;
- initiate a revegetation program based on locally sourced propagating material representative of indigenous species and vegetation communities present.

6.2.4 Management Actions

Wesfarmers–Marubeni would:

- fence the perimeter of the Project Area to exclude stock. Fencing, will not be provided to natural barriers, such as the tidal sections of the Keep River and the Weaber Range escarpment;
- arrange for pastoralists to remove stock from the Project Area.

The EME would:

- develop and implement a Fire Management Plan (Section 5.5);
- regularly monitor the conservation area for stock and arrange for their removal if any are detected;
- develop and implement a Weeds, Plant Pathogens and Pest Animals Management Plan (Section 6.3);
- obtain the necessary permits for the collection of seeds from native species;
- undertake rehabilitation of disturbed areas utilising locally sourced topsoil and seeds from native species;
- provide temporary fencing and signage to any revegetated areas;
- monitor the success of revegetation methods and modify as necessary.

6.3 WEEDS, PLANT PATHOGENS AND PEST ANIMALS MANAGEMENT PLAN

6.3.1 Background

The most effective and environmentally acceptable method of controlling new weed species and animal pests is to prevent their introduction. All staff and contractors should be made aware of the need to prevent the introduction of new weed species and animal pests into the Project Area. Weeds along the rivers and creeks should be targeted in particular wild passionfruit and caltrops which exist in the Project Area prior to development.

Feral animals recorded from the Project Area include cats, rats and mice.

6.3.2 Risk Assessment

The EME is obliged to manage pest species on the farm land and in the conservation areas in order to ensure minimal land degradation. Failure to do so could result in prosecution from the State and Territory authorities and deleterious changes to the ecology of the Project Area.

6.3.3 Objectives

The objectives for controlling weeds and pest animals and for dealing with plant and animals diseases are to:

- prevent the introduction of weed species and plant and animal diseases;
- control the introduction and spread of feral animals and vermin;
- eliminate declared and environmental weeds;
- minimise the spread of existing weed species;
- control pest animals in the conservation areas.

6.3.4 Management actions

Wesfarmers–Marubeni and the Water Corporation would:

- ensure clearance and disturbance of native vegetation during construction is minimised and vegetation rehabilitation accomplished quickly, thereby avoiding the creation of suitable areas for weed and plant pathogen invasion;
- ensure mandatory interstate quarantine are maintained during construction to control weeds from other areas;
- require construction contractors to carry out cleaning, where appropriate, of all vehicles and maintenance materials of soil and organic debris prior to arriving at the site;
- ensure site vehicles are restricted as much as possible to within the Project Area;
- require construction contractors to source borrow from weed free sites.

The EME would:

- regularly (annual) monitor and prepare a summary of the main areas of weed infestations within the conservation area;
- notify the Weed Science Section of AGWEST or the Department of Primary Industries and Fisheries (Northern Territory) of any declared weeds observed in the Project Area, and consult with the agencies to ensure compliance with relevant legislation and to ensure the implementation of appropriate control measures;
- develop methods for weed control where possible, ensuring acceptable controls are used when removing weeds near water courses;
- ensure constant monitoring of problem weed species is carried out and that effective control methods are undertaken before the populations are deemed a problem;
- take adequate measures to prevent the introduction and spread of new weed species and plant pathogens by:
 - undertaking equipment, plant and vehicle cleaning as necessary;
 - requiring all soil materials delivered to the site is certified weed and disease free;
 - ensure that quarantine inspection and clearance certificates are available for all interstate equipment and vehicles;
- ensure that species used in revegetation are suitable plants indigenous to and collected from the area;
- investigate immediately any area of vegetation which was apparently healthy and which, for no obvious reason, wilt and/or die to determine the presence of plant pathogens, changes in water levels or quality;
- control or eradicate feral fauna ensuring that no native fauna species are jeopardised;
- prohibit all unauthorised animals from the Project Area (eg. no cats and dogs);

- seek advice and expertise from authorities on all topics of this sub-plan as necessary.

6.4 BIODIVERSITY AND NATURE CONSERVATION MANAGEMENT PLAN

6.4.1 Background

Protection of the natural environment is a high priority. Conservation areas have been selected to conserve the natural assets of the Project Area, as consistent with the proposed development, and to implement ecologically sustainable management.

6.4.2 Risk Assessment

The proposed conservation area includes several priority flora and fauna species, vegetation communities and habitats. The farm development must not have a negative impact on the biodiversity of the conservation area. If it does, the Project may suffer a poor public image and the integrity of the EME may decline.

6.4.3 Objectives

The objective is to protect the conservation area during the development of the Project Area and during ongoing operations.

6.4.4 Management Actions

During construction, Wesfarmers–Marubeni and the Water Corporation would:

- ensure conservation of all important existing habitats by the conservation of representative vegetation communities;
- ensure areas designated for construction works are clearly marked on development maps and on the ground prior to commencement of work;
- require progressive rehabilitation of sites disturbed during development by construction contractors, especially drainage channels;
- require environmental and cultural heritage induction programs for all contractors and consultants working in the Project Area.

During operations, the EME would:

- maintain firebreaks and access tracks in the conservation areas;
- monitor and remove noxious and environmental weeds and pest animals;
- review maintenance proposals to ensure the extent of vegetation clearing for every maintenance activity is consistent with:
 - needs for the specific task;
 - requirements for bushfire control (access tracks);
 - priority conservation of significant areas of vegetation, wildlife habitats, corridors and other areas of significance;

- the maintenance of areas containing significant plant communities, species and animal habitats.
- develop and maintain public access points to the Keep River;
- monitor the use of the conservation area to ensure there is no deliterious use that could lead to degradation;
- brief all contractors and establish construction site guidelines as per the EMP;
- establish liaison with all regional and surrounding landholders who are involved with the active land management of properties;
- develop education material on nature conservation and implement as part of the environmental education and training program.