Government of **Western Australia**
Department of **Water**

Lower Ord River environmental water provisions monitoring program and management framework

Looking after all our water needs

Lower Ord River environmental water provisions monitoring program and management framework

Looking after all our water needs

Department of Water
Environmental water series report
Report no. 19
June 2011

Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601

National Relay Service 133 677

www.water.wa.gov.au

June 2011

ISSN 1833-6582 (print)
ISSN 1833-6590 (online)

ISBN 978-1-921789-56-4 (print)
ISBN 978-1-921789-57-1(online)

Acknowledgements

This report was prepared by Robyn Loomes and Mike Braimbridge from the Department of Water's Environmental Water Planning Section. The authors acknowledge the input and comments provided by Duncan Palmer, Rob Cossart, Clare Mason and Fiona Lynn.

For more information about this report, contact Robyn Loomes, Environmental Officer, Water Allocation Planning.

Telephone 08 6364 7600

Facsimile 08 6364 7601

Contents

Figures

Tables

Summary

This report describes the monitoring program developed to support lower Ord River environmental water provisions (EWP). The EWP are based on revised ecological water requirements (EWR) which set a range of wet and dry season flow targets to meet specific ecological objectives.

The aim of the EWP is to ensure that water is provided for irrigation and hydropower generation while minimising risks to environmental and social values in the lower Ord. This is particularly important in light of the proposed irrigation expansion project (M2), which is due to commence in 2012.

The EWP have been incorporated into Water Corporation's operating strategy, *A strategy for managing the flow of the Ord River from Lake Argyle to Reedy Creek by operation of the Ord River and Kununurra Diversion dams* (Department of Water 2009) as a set of rules to ensure the environmental flows are maintained. The rules are included in the Ord Allocation Plan due to be released in late-2011.

Monitoring is a key component of water allocation plan implementation particularly when an environmental flow regime is part of that plan. To support the Ord River allocation plan a management framework and monitoring program is required.

The monitoring program set out in this document was developed around a three part approach:

1. EWP flows: ensures the dams are operated to deliver the required EWP flows, incorporated into Water Corporation's operating strategy (DoW 2009)
2. flow objectives: tests whether specific ecological flow objectives are being met by EWP flows
3. ecological: tests whether the EWP flows are maintaining the ecological condition of the lower Ord River.

The ecological monitoring program incorporates the ecosystem components used to set the EWR: fish, macroinvertebrates, vegetation and water quality. It describes the location, method and frequency of monitoring for each component. The program is an extension of the environmental flows work completed in 2006. It will complement Ord Irrigation Cooperative's (OIC) existing monthly monitoring of water quality in irrigation drains, required under their operating strategy (Ord Irrigation Cooperative Limited 2009).

The ecological monitoring program defines a set of thresholds/ trigger levels for each ecological component. If a threshold is breached a management response framework sets out the roles and responsibilities of the DoW, Water Corporation and the OIC. The trigger levels will be reviewed after each monitoring round to ensure they are appropriate to meet the EWR objectives.

1 Introduction

1.1 Monitoring and planning context

This report describes the monitoring program developed to support lower Ord River environmental water provisions (EWP). The EWP are based on environmental water requirements (EWR) developed using the Flow Events Methodology. Analyses identified wet and dry season flow targets to meet the requirements of a series of flow ecology linkages (Braimbridge and Malseed 2007).

The timeline for development and revision of the EWR and EWP for the lower Ord River is as follows:

- 1999: interim EWR developed
- 2000 – 2006: additional ecological investigations
- 2006 – 2007: existing EWR revised
- 2007: EWP defined taking M2 into consideration
- 2008: monitoring program recommended
- 2009: EWP incorporated into operating strategy for the dams as a set of rules to ensure environmental flows are maintained.

The EWP will be included in the Ord Allocation Plan due to be released in late-2011.

1.2 Monitoring framework

The monitoring program is an extension of the environmental flows work completed in 2006. Monitoring is a key component of water allocation plan implementation particularly when an environmental flow regime is part of that plan.

The monitoring program set out in this document was developed around a three part approach or framework designed to answer the following questions:

1. EWP flows: are the EWP flows provided in accordance with the Water Corporation’s operating strategy rules (DoW 2009)?
2. flow objectives: are specific ecological flow objectives (for example, depth over riffle bars) being met by the EWP flows?
3. ecological outcomes: are the EWP flows maintaining the ecological condition of the lower Ord River?

2 EWP flow monitoring

2.1 Approach

Lower Ord River flows are monitored using the Tarrara Bar river gauging station, maintained and operated by the department (Tarrara Bar gauging station reference no. 809339). The department provides daily flow data to the Water Corporation, as dam operators, to enable flow releases from the Ord Main and Kununurra Diversion dams to meet EWP compliance requirements.

EWP flow monitoring is also incorporated into the management response and trigger framework that underpins the ecological monitoring.

Targets

The flow regime to be maintained in the lower Ord River between the confluence of the Dunham River and House Roof Hill (Figure 1) consists of a continuous baseflow component and a set of higher flow events.

The baseflow component is to be maintained throughout the year. The required flow rates are a function of the month of the year and the class of restriction (class 1 or 2 based on levels in Lake Argyle) applicable at the time (Table 1).

Table 1 Minimum flows to be measured at Tarrara Bar gauging station

	Lake Argyle water levels above which full EWP is met	**EWP**	**Range of water levels in Lake Argyle - 1st level restrictions**	**Restricted EWP (1st level)**	**Lake Argyle water levels below which 2nd level restrictions are applied**	**Restricted EWP (2nd level)**
	m AHD	**m^3/s**	**m AHD**	**m^3/s**	**m AHD**	**m^3/s**
January	79.2	50	-	-	79.2	39
February	82.0	57	-	-	82.0	44
March	83.4	57	-	-	83.4	44
April	83.7	53	-	-	81.0	41
May	83.2	48*	83.2 to 79.4	37	79.4	32
June	82.8	42	82.8 to 76.8	37	76.8	32
July	82.3	42	82.3 to 76.2	37	76.2	32
August	81.7	42	81.7 to 75.3	37	75.3	32
September	81.1	42	81.1 to 74.3	37	74.3	32
October	80.5	42	80.5 to 73.1	37	73.1	32
November	80.0	42	80.0 to 75.7	37	75.7	32
December	79.5	42	79.5 to 75.3	37	75.3	32

* on 15 May the EWP flow requirement drops from $48m^3/s$ to $42m^3/s$

During the wet season a set of higher flows are to be met for a specified number of days in four out of five wet seasons. These events inundate and maintain habitats, such as riparian benches (important for aquatic flora and fauna) and riparian vegetation.

The wet season flow requirements (Table 2) are expected to be achieved at the Tarrara Bar gauging station by the end of the wet season, 30 April. Flow targets will change if Lake Argyle water levels change (from drought to non-drought or vice versa) during the course of the wet season.

Table 2 Wet season peak flow targets

Number of events	Total target duration (days)	Duration remaining if (higher) flow targets have been met (days)	Average daily discharge (m^3/sec)	
			Unrestricted conditions Lake Argyle levels > 82.0 mAHD (Feb) > 83.4mAHD (Mar) and > 83.7mAHD (Apr)	Restricted conditions Lake Argyle levels < 82.0 mAHD (Feb) < 83.4mAHD (Mar) and < 83.7mAHD (Apr)
1	2	-	≥ 425	-
2	5	3	≥ 200	≥ 154
4	10	5	≥ 125	≥ 96
NA	18	8	≥ 100	≥ 77

Less frequent flood events also form part of the EWP regime (Table 3). These are expected to occur naturally from unregulated runoff from the Dunham River catchment and the catchment between the dams.

Table 3 Infrequent wet season flood events

Flood event	Average daily discharge (m^3/sec)
1 event (2 days duration) in 2 out of 3 years	≥ 425
1 event every 2 years	≥ 750
1 event every 4 years	≥ 1400
1 event every 27 to35 years	≥ 3700

2.2 Reporting

The water year for this scheme is 1 May to 30 April. This has been based on the change in seasons. For the purpose of this strategy the dry season is considered to occur between 1 May and 31 October and the wet season between1 November and 30 April.

The Water Corporation will submit a draft monitoring report to DoW each year, indicating compliance with the scheme's operation strategy. Compliance with the prescribed environmental flow targets, based on mean daily flows at Tarrara Bar, is a key component of the annual report.

To support the implementation of wet season peak flow targets, the Water Corporation is required to conduct an interim review of the flow record for each wet season by the end of January each year. If wet season targets have not been met in the current wet and were not achieved in one or more of the preceding four wet seasons, additional top up flows are triggered. This requires an increase in the frequency of flow monitoring at Tarrara Bar and in the Dunham River. If flows are approaching targets the extra top up releases are to be made.

3 Flow objectives monitoring

An hydraulic model of the lower Ord River was used to estimate the flows required to meet ecological thresholds (Braimbridge & Malseed 2007). This monitoring tests the accuracy of the flow model by measuring the water level in the river at a range of flow rates and comparing it with the water level predicted by the model. This calibration focuses on critical flows and flow thresholds identified in the EWR.

3.1 Approach

The Department of Water will undertake this work. It requires short-term measurement of stage heights at cross-sections on the lower Ord River. Data loggers will be installed between October and June to capture wet season flows.

Cross-sections are selected to represent the different habitat types addressed by specific target flows. The sites were surveyed by a licensed surveyor to allow reference to existing cross-sections used in the hydraulic model.

3.2 Reporting

Logger data will be analysed to determine how well the hydraulic model predicts the flows required to meet ecologically critical thresholds.

If the analysis shows there is significant error in the hydraulic model, that is, if the model predicted water levels are very different from the measured water levels, revision of the flow targets may be required.

Provided there are not significant changes to the channel morphology of the river, this monitoring will only be undertaken every five years.

4 Ecological monitoring

The ecological monitoring program incorporates the ecosystem components used to set the EWR (for example, fish, macroinvertebrates, water quality). It is based on a program proposed by WR&M (2008), but has been refined to optimise monitoring effort (see Appendix A for differences between programs).

The aims of the proposed ecological monitoring are to:

- increase our understanding of ecosystem thresholds and resilience
- continue collection of baseline data (prior to Stage 2)
- review and refine EWP if required
- manage and protect existing ecological values of the lower Ord River.

4.1 Approach

The program has two stages. Firstly, intensive annual monitoring is planned prior to the proposed expansion of the Ord irrigation area. Combined with existing data this will capture a strong baseline dataset. Secondly, following expansion, we will implement an ongoing program, undertaking detailed monitoring every three years.

The following ecological and biological parameters will be monitored:

- water quality (physico-chemical parameters, nutrients and toxicants) and primary productivity
- macroinvertebrates
- fish
- riparian and in-stream vegetation.

The previous water quality monitoring program will be implemented and will include simple measures of primary productivity.

Monitoring sites

Monitoring is restricted to Reaches 1 and 2 as the biota in tidal-dominated Reach 3 (Figure 1) are likely to be significantly different, representing both estuarine and freshwater species. The Department of Environment and Conservation currently manages the Ramsar listed area of the lower Ord River floodplain and Parry Lagoon, both in Reach 3.

In addition to monitoring sites on the lower Ord River, reference (control) sites have also been selected. This will help differentiate between natural changes in ecology due to variations in regional climate and those that may be caused by changes to the lower Ord River flow regime.

In selecting reference sites it was recognised that all rivers in the region, other than the Ord, are non-regulated. There will therefore be differences in flow and the composition of flora and fauna between reference river and Ord River sites. However, the reference sites will still provide a stable benchmark against which changes in the Ord can be assessed.

Monitoring and reference sites were selected based on previous ecological studies and were verified in the field in October 2009.

4.2 Reporting

Water quality will be monitored monthly and samples shipped to Perth for analysis. OIC currently monitor water quality in irrigation drains and store data on the department's Water Information database (WIN). Under their operating strategy OIC report exceedances of water quality triggers to DoW within seven days of detection along with information on the source of the breach and how the issue has been rectified (Ord Irrigation Cooperative Limited 2009). OIC also report all monitoring results in an annual report to the department.

Reporting on breaches by DoW or OIC as they occur should continue and actions implemented as per the response framework (Figure 2, Table 4).

Consultants undertaking dry season macroinvertebrate, fish and vegetation monitoring will report results to the DoW by the end of the following wet season.

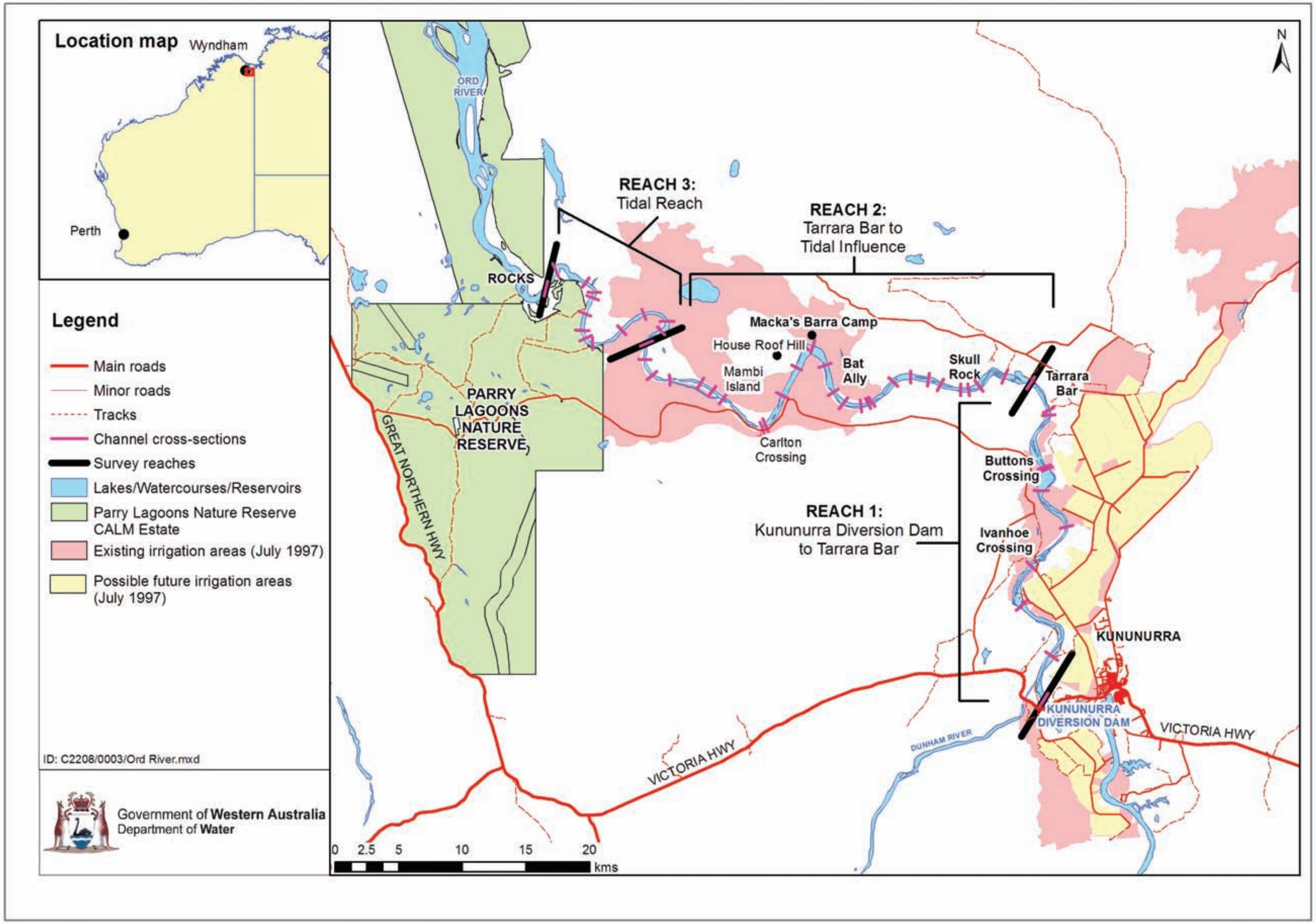

Figure 1 Lower Ord River

5 Management trigger and response framework

For each ecological component of the monitoring program a biological or ecological threshold has been identified. This is the point at which predicted changes in flow may cause rapid change in the ecosystem.

When breaches of these thresholds are detected (for example, Dissolved Oxygen drops below 2 mg/L) a management response will be triggered. The type of management response will depend on the threshold that has been breached, the severity of that breach and if flow targets have been met.

The management response framework (Figure 2) shows the actions required following a breach of ecological triggers. Table 4 describes the role of the DoW, Water Corporation and Ord Irrigation Cooperative as part of the management response framework.

It is recommended that further baseline monitoring data be collected prior to managing according to ecological triggers. This will improve the understanding of the system and confirm thresholds are appropriate for the lower Ord.

Once trigger levels are in place, they will be applied to monitoring data. The trigger levels will be reviewed on an annual basis to ensure they are appropriate to meet the EWR objectives.

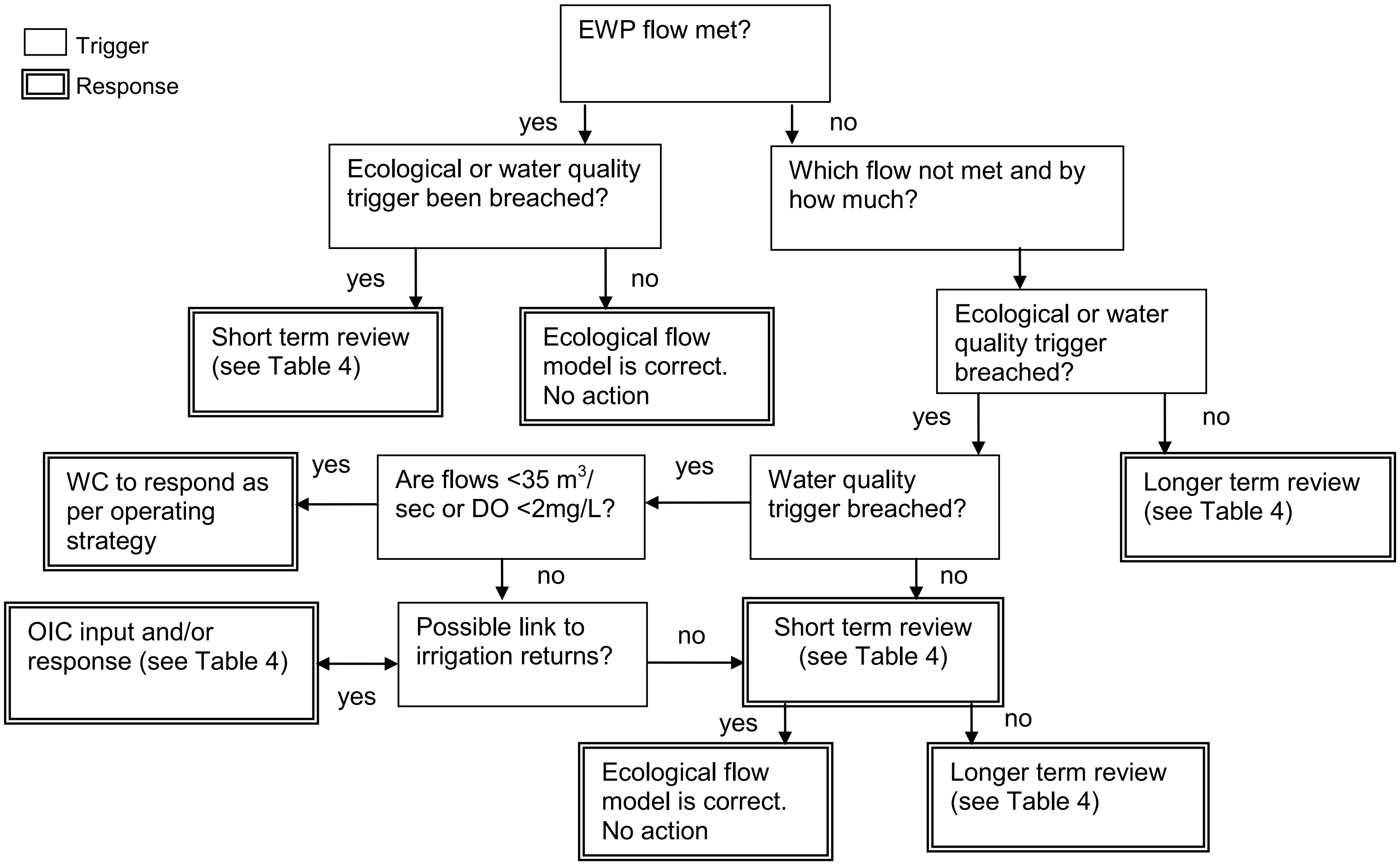

Figure 2 Lower Ord River EWP flow and ecological monitoring management trigger and response framework

Table 4 Management responses required by DoW, Water Corporation and Ord Irrigation Cooperative

EWP flow	**Is there an ecological trigger?**	**Actions**		
		Department of Water	**Water Corporation**	**Ord Irrigation Cooperative**
met	yes	• short term review (<6 months) of ecological flow model (may require input from expert panel) • response based on: o severity of impacts o certainty of cause o reference site response • revise operation strategy and amend if required.	• provide monitoring data as requested • implement revised operating strategy if required	• provide water quality data if requested • if breach detected investigate source, rectify issue and monitor impact
	no	no action required	• no action required	no action required
not met	yes	• analysis of ecological trigger and EWP component not met (may require input from Aquatic Science Branch)	• show cause of EWP flow breach • provide monitoring data as requested • meet operating strategy + revised operating strategy if required	• provide water quality data if requested • if breach detected investigate source, rectify issue and monitor impact
	no	• longer term review of: o ecological trigger o EWRs/ EWPs o operating strategy o allocation plan (may require input from expert panel)	• show cause of EWP flow breach • provide monitoring data as requested • meet operating strategy	no action required

6 Ecological monitoring program

6.1 Water quality and dissolved oxygen

Approach

Water quality

The potential for adverse impacts on water quality from irrigation returns were highlighted in 1997 by endosulfan poisoning of fish in the Dunham River and D4 irrigation drain (Fredricks 2006). In response the DoW and the OIC established a water quality monitoring program. The program ran from 1998 to 2008 and assessed levels of nutrient and non-nutrient contaminants (toxicants) associated with the Ord River Irrigation Area (ORIA). The program recognised two potential drivers of changes in water quality: altered flow regime and irrigation returns.

Although irrigation returns currently only contribute 2 to 5 m^3s^{-1} to dry season flows, it is estimated that return flow accounts for about one third of the total nitrogen load one quarter of total phosphorus and half of the dissolved inorganic nitrogen load (Robson et al. 2008).

The Ord expansion project and M2 channel may result in increased abstraction from the lower Ord, and potentially to increased concentrations of nutrients and contaminants (Trayler, Malseed & Braimbridge 2006). This may have a negative impact on aquatic species, like fish and macroinvertebrates. The OIC continue to monitor irrigation drains however, re-implementation of a lower Ord River program is now required to monitor potential future changes in water quality.

Primary productivity (growth of algae and plants) is the basis of riverine food-webs however, increases in productivity can be associated with deterioration in water quality (Robson et al. 2008). Targeted studies of primary productivity, examining diurnal oxygen curves and chlorophyll *a,* may be implemented if required.

Dissolved oxygen

Increased abstraction may reduce dry season flows. This increases the risk of low dissolved oxygen (DO) levels and possibly anoxia within river pool habitats. Dissolved oxygen concentrations depend on the difference between the supply of oxygen (from the atmosphere, inflow and photosynthesis by aquatic plants and algae) and the consumption of oxygen in the pool (respiration and biological and chemical oxidation processes) (Trayler, Malseed & Braimbridge 2006).

Fish deaths can occur where the whole water column becomes anoxic and sublethal effects on fish (for example, reduced egg viability) can develop where oxygen levels fall below about 2 mg/L.

Additional dissolved oxygen (DO) monitoring is therefore needed to ensure there is enough water in pools during low flow/ drought periods to prevent anoxia and possible fish kills.

This requires the deployment of DO loggers if flows at Tarrara Bar are expected to fall below a recommended trigger level of 35 m^3/sec. If measured DO levels fall below 2 mg/L flows will be increased. This trigger has been incorporated in to the Water Corporation's operating strategy (Department of Water 2009).

Details of the water quality monitoring program are shown in Table 5. Further information on monitoring sites is shown in Appendix C.

Table 5 Approach to water quality and dissolved oxygen monitoring

Where	
Water quality	• 5 main channel sites (refer Appendix C) • 3 reference sites • 8 drains – OIC monitored
Total sites	• 8 DoW + 8 OIC
Intensive DO	• Loggers (type to be determined) 1 upstream of Tarrara Bar, 1 at Carlton Crossing as per WC's Ord operating strategy
What/ how	
Water quality	• Physico-chemical parameters (DO, EC, pH, temperature) measured in-situ with hand-held probe • Collect 2 x 1 L samples, store on ice in field at 4^{o}C until shipped to lab (within 24 hours). Analyse/ calculate TN, TKN, TP, chloride ion, TSS, NO_x, NH^3-N/NH^4-N, SiO^2, FRP, DON, DOP, DOC • Toxicants: predominantly atrazine and endosulfan (see Appendix B for complete list). Collect 1 L sample in pre-cleaned, brown glass bottle, store on ice in field, then at 1 to 4^{o}C until shipped to lab. Extract within 7 days • Targeted primary productivity studies would require chl *a* sampling
Intensive DO	• Loggers deployed when flows ≤35 m^3/sec and for duration of low flow period to detect DO ≤2 mg/L • Deployed from a star picket and kept within moving water column • Targeted primary productivity studies would require development of diurnal oxygen curves using logger data
When	
Water quality	• Monthly pre-development to qualify baseline dynamics • Post-development monthly monitoring for 3 years as per baseline
Intensive DO	• Loggers deployed when flows ≤35 m^3/sec and for duration of low flow period to detect DO ≤2 mg/L

Trigger levels

Water quality objectives are recommended in the ANZECC (2000) guidelines. Toxicants triggers were set at levels to preserve 'high quality environments' (99% species protection). However, due to long-term pastoral and irrigation activities along the Ord, nutrient trigger values were set to preserve 'slightly to moderately disturbed lowland tropical systems' (95% species protection).

Fredricks (2006) used water quality data collected at four local reference sites between 1998 and 2003 to develop local trigger values. These locally derived values were higher than ANZECC triggers and are therefore exceeded less frequently. This suggests that using data from local sites with elevated nutrients to develop less stringent guidelines (that is, to allow higher levels of contaminants) may place the ecology at a higher level of risk (WR&M 2008). However, the locally derived values are recommended here as they recognise the long-term impacts of surrounding land use. It is also recommended that the triggers be revised once sufficient baseline data are collected.

ANZECC and locally derived nutrient and physico-chemical parameter trigger values are shown in Table 6. Toxicant, trigger levels are presented in Appendix B.

Table 6 Nutrient and physico-chemical trigger values

Parameter	**Locally derived reference values**	**ANZECC 2000 trigger value**
total nitrogen (TN)	290 µg/L	300 µg/L
total phosphorus (TP)	18 µg/L	10 µg/L (baseflow)
filterable reactive phosphorus (FRP)	9 µg/L	5 µg/L
nitrate (NO_X)	14 µg/L	5 µg/L
ammonium (NH^{4+})	29 µg/L	10 µg/L (baseflow)
electrical conductivity (EC)	1000 mg/L	1000 mg/L
turbidity	14 NTU	2 NTU (baseflow)
total suspended solids (TSS)	7 mg/L	2 mg/L (baseflow)
dissolved oxygen (DO)	≤2 mg/L	≤2 mg/L

6.2 Macroinvertebrates

Approach

Macroinvertebrates are useful indicators in biological monitoring. In general they play a pivotal role in freshwater food webs (WR&M 2008). They are an important food source for fish and water birds and contribute to nutrient and carbon cycling (Trayler, Malseed & Braimbridge 2006). At least 171 taxa have been recorded in the lower Ord River (WR&M 2008).

Macroinvertebrates are found in a number of habitats. However, gravel/ cobble rapid runs, aquatic vegetation and emergent vegetation (rushes and sedges) are the most important macroinvertebrate habitats in the lower Ord River (WR&M 2008). Inclusion of these habitats in the monitoring program would also address the flow-ecology linkages described by Braimbridge and Malseed (2007).

The following monitoring objectives have been developed for macroinvertebrates in the lower Ord River. In each habitat type, in the mid-late dry season there is no change in:

- total number of macroinvertebrate species or community composition
- number of sensitive EPT taxa – Ephemeroptera (mayflies), Plecoptera (stoneflies) or Trichoptera (caddis flies) taxa that tend to be more sensitive to water quality than others
- number of high flow taxa – taxa more likely to respond to reductions in flow velocity
- SIGNAL scores (Stream Invertebrate Grade Number – Average Level) - families are scored based on sensitivity to water pollution and weighted by abundance
- SIGNALFLOW scores - SIGNAL scores which relate to flow sensitivity and are weighted by abundance.

It is anticipated that meeting these objectives will maintain the current suite of macroinvertebrate species and support their ecological role.

The monitoring will follow the AusRivAs (Australian River Assessment System) method, a rapid prediction system used to assess the biological health of Australian rivers. Details of recommended macroinvertebrate monitoring are shown in Table 7. Further information on monitoring sites is shown in Appendix D.

Trigger levels

Macroinvertebrate trigger levels are represented by a 10 per cent decline in the following parameters:

- total number of taxa or community composition
- high flow taxa
- number of sensitive EPT taxa
- SIGNAL and SIGNALFLOW scores.

Table 7 Approach to macroinvertebrate monitoring

Where	
Gravel/ cobble rapid runs	• Reach 1: 2 of 4 sites accessible from Buttons Crossing AND 2 of 6 accessible from Ivanhoe Crossing • Reach 2: 6 sites – 2 at Carlton Crossing, 2 at Bat Alley and 2 in vicinity of Sandy Beach (see Appendix 5)
Emergent and submerged vegetation	• Reach 1: 10 sites (5 emergent, 5 submerged) • Reach 2: 10 sites (5 emergent, 5 submerged) (see Appendix D)
References sites	• 1 each on the Keep, Dunham, Pentecost, Behn and Negri rivers
Total sites	• 30 + 5 reference
What/ how	
	• Total number of taxa • Community composition • Number of sensitive EPT taxa • High-flow taxa • SIGNAL and SIGNALFLOW scores
	• Standard AusRivAS methods for Western Australia with all taxa identified to lowest practical taxonomic level
	• Samples collected using 250 µm mesh D-net over 10 m of selected habitat and preserved in ethanol for processing
	• Standard AusRivAS habitat variables recorded at time of sampling
	• All sites geo-referenced with hand-held GPS and mapped
	• Statistical analysis following WR&M (2008)
When	
	• Annually during early to mid dry season (June–October) pre Ord stage 2 development, then every 3 years

6.3 Fish

Approach

Monitoring of fish in the lower Ord River has shown lower statistical power to detect change than monitoring of macroinvertebrates (WR&M 2008). However, as fish are of high social and ecological value on the lower Ord River, it is important to include them in the monitoring program.

Fish rely on a number of habitats for feeding and/ or breeding. Shallow backwaters and channel pools are the most important to dry season monitoring, as they are dependent on the flow regime (WR&M 2008). These habitats also support fish communities with low inter- and intra-annual variation in composition and structure, meaning they are better indicators of longer-term impacts of alerted flows.

Based on analysis of baseline data, five parameters were selected for ongoing monitoring of fish in both habitats:

1. total number of fish species
2. abundance of each species
3. species assemblages
4. proportion of freshwater, marine/ estuarine opportunist and catadromous individuals (live in freshwater, breed in the sea)
5. proportion of exotic individuals.

In addition species with a high occurrence in a specific habitat are indicators for that habitat. The number and size class distribution of:

- barramundi, mullet, blue catfish and Midgley's catfish in deep, channel pools
- flathead goby, bony bream and rainbowfish in shallow backwaters.

Details of recommended fish monitoring are shown in Table 8. Further information on monitoring sites is shown in Appendix E.

Trigger levels

Fish trigger levels are represented by a 30 per cent decline in the following parameters in deep pool habitat and shallow backwaters:

- total number of species
- abundance of each species.

The following additional triggers are required for key fish species. A detectable change in frequency of occurrence or size class distribution of:

- *Lates calcarifer* (barramundi), *Liza alata* (mullet), *Arius graffei* (blue catfish), *Arius midgleyi* (Midgley's catfish) in deep pools
- *Glossigobius giurus* (flathead goby), *Nematalosa erebi* (bony bream) or *Melanotaenia australis* (rainbowfish) in shallow backwaters.

The levels of detectable change should be reviewed and refined once baseline monitoring is complete.

Table 8 Approach to fish monitoring

Where	
	• 10 pool habitat and 10 shallow backwater sites across Reaches 1 and 2 (see Appendix E)
Reference sites	• As recommended for macroinvertebrates (1 each on the Keep, Dunham, Pentecost, Behn and Negri rivers)
Total sites	• 20 + 5 reference sites
What/ how	
	• Species richness • Abundance of species • Proportion of exotic individuals • Proportion of resident freshwater, marine/ estuarine opportunists and catadromous individuals • Size/ age of individuals
	• Shallow backwaters sampled using beach seine nets (20 m long, 1.5 m deep, 10 mm diamond mesh) deployed across mouth of backwater and drawn through habitat
	• Pools sampled using multi-panel gill nets (30 m nets with 6 x 5 m panels from 1” to 6” stretched mesh size) set for approximately 3 hours (morning or afternoon) at a 30 to 45 degree angle relative to bank, and checked frequently
	• All fish identified to species, weight and length recorded and released live (unless unidentified)
	• Physico-chemical and habitat descriptors measured at each site as per WR&M (2008)
	• All sites geo-referenced by hand-held GPS and mapped
	• Statistical analysis as per WR&M (2008)
When	
	• Annually during early to mid dry season (June–October) pre Ord stage 2 development, then every 3 years

6.4 Riparian and in-stream vegetation

Approach

Regulation of the Ord River has led to a reduction in high, wet season flows, and an increase in dry season flows. This has resulted in the reduced scouring of vegetation, increased sedimentation and an increase of riparian vegetation on river banks and emergent and submerged plants within the channel. Further flow reductions may lead to vegetation clogging the channel and changing its geomorphology over time.

Vegetation monitoring is also required to ensure that EWP flows are meeting their ecological objectives and maintaining riparian and instream flora.

Objectives for riparian and in-stream vegetation monitoring aim to maintain the:

- diversity of riparian vegetation
- extent of submerged and emergent vegetation
- current vegetation structure
- dominance of native species over weeds
- dominance of riparian species over terrestrial species.

It is anticipated that meeting these objectives will:

- prevent vegetation clogging the river channel
- provide habitat for macroinvertebrates and fish
- provide shade and organic inputs to the river channel
- stabilise banks
- filter contaminants.

Details of recommended vegetation monitoring are shown in Table 9. Further information on vegetation monitoring sites is shown in Appendix F.

Table 9 Approach to vegetation monitoring

Where	
Existing[1]	• Reach 1: Kirby's, Kununurra Research Station and Buttons Crossing • Reach 2: Sandy Beach north and south bank, The Gate/ Bat Alley, upstream and downstream of Carlton Crossing/ Roof Top Hill • Reach 3: The Loop inaccessible and Parry Lagoon non-representative vegetation – remove both sites from program
Additional	• Reach 1: Lake Kununurra – re-establish at new location • Reach 2: Mambi Island boat ramp • Reach 3: no sites
Reference	• Vegetation: Dunham River/ Great Northern Highway crossing
Total sites	• 11 + 1 reference site
What/ how	
Vegetation	• Permanent, marked 20 m wide riparian transects running perpendicular to river channel • Minimum two 5 x 5 m quadrats within each vegetation area (that is, dry upper bank, flood prone mid-bank, damp channel margin, submerged channel bed) • Submerged vegetation monitored from bank or boat due to risk of crocodile attack • Within each quadrat all species identified, life forms recorded, cover and abundances estimated using Domin-Krajina scale • All trees (>3 m) tagged, stem diameter at breast height (dbh) and transect distance of each recorded, canopy condition assessed (using 3 point scale – canopy density, proportion of dead branches, and epicormic growth) • Substrate and surface factors recorded following attribute and cover classes outlined in WR&M (2008) • Set-point photography • Statistical analysis following WR&M (2008)
When	
	• Mid-late dry season (July-October) pre Ord stage 2 development, then every three years

[1]established by Croot (2002) and Start, Wyroll & Handasyde (2002)

Trigger levels

The recommended vegetation trigger levels follow those developed by the Environmental Protection Agency (2000) and adapted in Froend and Loomes (2004) (Table 10). Trigger levels will be reviewed and refined once baseline monitoring is complete.

Table 10 Vegetation triggers

Parameter	Trigger
Species composition	• Measurable encroachment of terrestrial species • Measurable increase in abundance of exotic submerged/ emergent macrophytes
Species distribution	• Measurable contraction of riparian vegetation as changes in size/ age class structure of more than one species • Measurable contraction of in-stream vegetation, not related to a high flow event
Species mortality	• Greater than 15% reduction in abundance of dominant species
Species richness	• Measurable decline of riparian species and/ or increase in terrestrial species • Measurable decline of in-stream vegetation
Species recruitment	• No indication of recent (5 years) overstorey recruitment
Community structure	• Notable change
Density and cover and abundance	• Measurable crown dieback in overstorey and/ or reduction in cover of understorey

Appendices

Appendix A Differences between monitoring program proposed by WR&M (2008) and recommended program

Component	WR&M (2008)	Revised program	Why it was changed
Water quality			
• Monitoring frequency	Weekly/ fortnightly	Monthly	Too frequent
• Primary productivity	Single station diurnal oxygen curves, chl *a* and carbon 13 ($\delta^{13}C$)	Diurnal oxygen and chl *a*	Primary productivity low priority
Vegetation and geomorphology			
• Approach	Aerial photography and on ground assessment	Geomorphology not assessed On ground assessment	Cost
• Sites	Reaches 1, 2 and 3	Reaches 1 and 2	Reach 3 is tidal
• Reference sites	8 sites	1 site (Dunham River)	Existing site on unregulated river
Macroinvertebrates			
• No. sites	10 of each habitat in each reach	10 of each habitat across reaches 1 and 2	Reduce sampling effort and cost
• No. reference sites	10	5	Reduce sampling effort and cost
• Sampled habitats	Gravel/ cobble runs	Gravel cobble runs emergent vegetation and submerged vegetation	Other habitat types recognised as important in EWP
Fish			
• No. of sites	10 of each habitat in each reach	10 of each habitat across reaches 1 and 2	Reduce sampling effort and cost
• No. of reference sites	10	5	Reduce sampling effort and cost
• Sampled habitats	Shallow backwaters, deep pools and flooded riparian vegetation	Shallow backwaters and deep pools	Reduce sampling effort and cost
• Sampling season	Wet and dry	Dry only	Reduce sampling effort and cost
• Additional data collection	CPUE (catch per unit effort) and length frequency by charters	Not recommended	changes to log books and co-operation of charter operators
Functional habitat			
• Monitoring approach	Aerial with ground-truthing	Not recommended	Reduce time and cost
• Habitats	9 types		Reduce time and cost

Appendix B Default ANZECC (2000) guideline values for toxicants

Level of protection (% species)	Chemical trigger values for freshwater (ugL-1)			
	99%	**95%**	**90%**	**80%**
Organochlorine pesticides				
Aldrin B	ID	ID	ID	ID
Chlordane B	0.03	0.08	0.14	0.27A
DDE B	ID	ID	ID	ID
DDT B	0.006	0.01	0.02	0.04
Dicofol B	ID	ID	ID	ID
Dieldrin B	ID	ID	ID	ID
Endosulfan B	0.03	0.2A	0.6A	1.8A
Endosulfan Alpha B	ID	ID	ID	ID
Endosulfan Beta B	ID	ID	ID	ID
Endrin B	0.01	0.02	0.04A	0.06A
Heptachlor B	0.01	0.09	0.25	0.7A
Lindane	0.07	0.2	0.4	1.0A
Methoxychlor B	ID	ID	ID	ID
Mirex B	ID	ID	ID	ID
Toxaphene B	0.1	0.2	0.3	0.5
Azinphos methyl	0.01	0.02	0.05	0.11A
Chlorpyrifos B	0.00004	0.01	0.11A	1.2A
Demeton	ID	ID	ID	ID
Demeton-S-methyl	ID	ID	ID	ID
Diazinon	0.00003	0.01	0.2A	2A
Dimethoate	0.1	0.15	0.2	0.3
Fenitrothion	0.1	0.2	0.3	0.4
Malathion	0.002	0.05	0.2	1.1A
Parathion	0.0007	0.004C	0.01C	0.04A
Profenofos B	ID	ID	ID	ID
Temephos B	ID	ID	ID	ID
Carbamate and other pesticides				
Carbofuran	0.06	1.2A	4A	15A
Methomyl	0.5	3.5	9.5	23
S-methoprene	ID	ID	ID	ID
Deltamethrin	ID	ID	ID	ID
Esfenvalerate	ID	0.001	ID	ID
Herbicides and fungicides				
Diquat	0.01	1.4	10	80A
Paraquat	ID	ID	ID	ID
MCPA	ID	ID	ID	ID
2,4-D	140	280	450	830
2,4,5-T	3	36	100	290A
Bensulfuron	ID	ID	ID	ID
Metsulfuron	ID	ID	ID	ID
Molinate	0.1	3.4	14	57
Thiobencarb	1	2.8	4.6	8C
Thiram	0.01	0.2	0.8C	3A
Amitrole	ID	ID	ID	ID
Atrazine	0.7	13	45C	150C

Hexazinone	ID	ID	ID	ID
Simazine	0.2	3.2	11	35
Diuron	ID	ID	ID	ID
Tebuthiuron	0.02	2.2	20	160C
Acrolein	ID	ID	ID	ID
Bromacil	ID	ID	ID	ID
Glyphosate	370	1200	2000	3600A
Imazethapyr	ID	ID	ID	ID
Ioxynil	ID	ID	ID	ID
Metolachlor	ID	ID	ID	ID
Sethoxydim	ID	ID	ID	ID
Trifluralin B	2.6	4.4	6	9A

A - Figure may not protect key test species from acute toxicity (and chronic)
B - Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered.
C - Figure may not protect key test species from chronic toxicity
ID - Insufficient data to derive a reliable trigger value.

Appendix C Water quality monitoring site locations

Site location	Name	Code	E	N
Supply channel sites*	M1 Off take	OM1O	469819	8254031
	Packsaddle Supply Channel – delivery	OPSC	473344	8246470
	Stock Route Road	OSRR	472207	8269980
Drainage sites*	Drain 1 Drop	OD1D	469433	8259667
	Drain 2 b Drop	OD2BD	470590	8266022
	Drain 4 Holdfast Crossing	OD4HOLX	469283	8277695
	Drain 8 Culvert	OD8C	482251	8285608
	Packsaddle Creek Road Crossing	OPCRX	465452	8253245
River sites	Carlton Crossing	OCARLX	445893	8275766
	Dunham River Road Bridge	ODRRB	465702	8254600
	Ivanhoe Crossing	OIVANX	466500	8265687
	Drovers Rest	ODROVR	467690	8277181
	Tarrara Bar	OTARB	466042	8279568
Reference sites	Maxwell Plains	OMAXP	475330	8244131
	Flying Fox Hole	OFFOXH	457453	8249671
	Lilly Creek Lagoon	OLCLAG	472037	8254537

** currently monitored by OIC*

Appendix D Macroinvertebrate monitoring site locations

Habitat/ reach	Comments/ access
Gravel riffle/ cobble rapid run	
Reach 1: 4 sites selected from:	
2 downstream of Buttons Crossing	1 north and 1 south of island on rapid section at Drovers Rest, near outflow of irrigation drain D3
1 upstream Buttons Crossing	rapids immediately upstream
1 upstream of Buttons Crossing	~ 400 m upstream
1 at bottom end of Ivanhoe Crossing pool ~2 km downstream	upstream from Kununurra Research Station (KRS) vegetation site, road access from KRS
1 at launching area	~ 1 km downstream from Ivanhoe crossing
2 at Ivanhoe Crossing	1 east, 1 west
2 between Kununurra Diversion Dam (KDD) and Ivanhoe Crossing	
Reach 2: 6 sites	
2 sites at Carlton Crossing	1 upstream and 1 downstream
2 at Bat Alley	1 upstream and 1 downstream end
2 in vicinity of Sandy Beach	1 at Sandy Beach 1 at the gravel bar ~ 1 km downstream
Emergent vegetation	
Reach 1: 5 sites	
To be determined by contractor	
Reach 2: 5 sites	
To be determined by contractor	
Submerged vegetation	
Reach 1: 5 sites	
1.5 km north of Skull Rock	
Near KRS vegetation transect	east side of river, access from Research Station Rd
Reach 2: 5 sites	
downstream Carlton Crossing	south side of river, access Parry Creek–Kununurra Rd before Hairy Dog's fishing camp
Sandy Beach South	north side of river, access from Parry Creek–Kununurra Rd, existing geomorphology site

Appendix E Fish monitoring site locations

Habitat/ reach	Comments/ access
Deep Pools	
Reach 1: 5 sites	
Kirby's – 2 sites	boat access from KDD
Kununurra Research Station	boat access from west side of Ivanhoe Crossing
Buttons Crossing	5 km pool, boat access from Buttons Crossing
Upstream of Ivanhoe Crossing	boat access from River Farm Rd or Ivanhoe Crossing
Reach 2: 5 sites	
Sandy Beach to Tarrara Bar	road or boat access from Skull Rock, east side of Ord
Downstream Carlton Crossing	boat access from Mambi Island boat ramp
Carlton Crossing to Sandy Beach – 3 sites including Bat Alley	fast flowing
Shallow backwaters	
Reach 1: 5 sites	
Between KDD and Kirby's – 2 sites	east side of river, boat access
Kirby's	access from KDD
Between Ivanhoe and KRS	west side, access Ivanhoe Crossing
Downstream of Buttons Crossing (Drover's Rest to D4)	west side, access Buttons Crossing
Reach 2: 5 sites	
Tarrara Bar to Sandy Beach	south-west side, access Skull Rock
Tarrara Bar to Sandy Beach	creek on s/w side, boat access Skull Rock
Tarrara Bar to Sandy Beach	shallow creek (with crocodile)
Tarrara Bar to Sandy Beach	road access 1 km east of boat ramp
Downstream Sandy Beach	access Sandy Beach
Downstream Mambi Island (boat ramp) – 2 sites	access Mambi Island (boat ramp)
The Gate/ Bat Alley	large backwater west of main channel

Appendix F Vegetation monitoring transect locations

Site name	E	N	length (m)	Location/ access
Kirby's	467193	8260362	152	West side of river, access from Valentine Creek Rd (new urban development)
Kimberley Research Station	467233	8269988	230	East side of river, access from Research Station Rd and through KRS
Sandy Beach North	459109	8279415	329	North side of river, access from Skull Rock boat ramp
Sandy Beach South	458142	8279178	357	North side of river, access from Parry Creek-Kununurra Rd
The Gate/ Bat Alley	451002	8279300	295	North side of river, access from Carlton Hill Rd
Lake Kununurra*	471016	8253120	To be determined	Access Packsaddle Rd. Replaces existing site
Buttons Crossing	466664	8273098	200	South side of river, access from Parry Creek–Kununurra Rd
Carlton Crossing/ House Roof Hill – upstream	446068	8275660	50	South side of river, access Parry Creek–Kununurra Rd before Hairy Dog's fishing camp
Carlton Crossing/ House Roof Hill – downstream	To be determined		50	South side of river, access Parry Creek–Kununurra Rd before Hairy Dog's fishing camp
Mambi Island boat ramp*	443593	8277320	To be determined	Replaces the Loop site. South of river, access from Parry Creek–Kununurra Rd
Dunham River (Excelsior Pool)	432513	8213838	100	*Reference site*, access off Great Northern Highway old alignment

*new sites

Appendix G Map disclaimer

Figure 1

Datum and projection information

Vertical Datum: Australian Height Datum

Horizontal Datum: Geodetic Datum of Australia

Projection: GDA 94 MGA Zone 52

Spheroid: Australian national Spheroid

Project information

Client: Robyn Loomes

Map Author: Michelle Antao

This map is a product of the Department of Water, Water Resources Use Division and was printed May 2011.

These maps were produced with the intent that they be used for information purposes at the scale as shown when printing.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, the Department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Sources

DoW acknowledges the following datasets and their Custodians in the production of this map:

Scientific Data Locations - WRC - July 2002

Roads - DOLA/AUSLIG - December 1999

Canals/Watercourses/Lakes - AUSLIG - December 1997

CALM Estate - CALM - March 1998

Irrigation Areas - WRC - July 1997

Shortened forms

ANZECC	Australian and New Zealand Environment Conservation Council
AusRivAS	Australian river assessment system
DO	dissolved oxygen
DoW	Department of Water
EC	electrical conductivity
EFT	Ephemeroptera, Plecoptera and Trichoptera taxa
EWP	environmental water provision
EWR	ecological water requirement
GPS	global positioning system
mAHD	metres Australian height datum
OIC	Ord irrigation cooperative
SIGNAL	stream invertebrate grade number – average level
WC	Water Corporation

Glossary

Anoxia	A pathological absence of oxygen.
Baseflow	The component of stream flow supplied by groundwater discharge.
Channel morphology	The physical form and structure of a river channel.
Dissolved oxygen (DO)	The concentration of oxygen dissolved in water of effluent, normally measured in milligrams per litre (mg/L).
Ecological water requirement	The water regime needed to maintain ecological values of water-dependent ecosystems at a low level of risk.
Ecosystem	A community or assemblage of communities of organisms, interacting with one another and with the specific environment in which they live, for example, a lake. Includes all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Environmental flows	The streamflow needed to maintain the ecological values of surface water dependent ecosystems.
Environmental water provision	The water regimes that are provided as a result of the water allocation decision-making process taking into account ecological, social and economic values. They may met in part or full the ecological water requirements.
Flow ecology linkage	Describes the link between components of the ecology or ecologically important features of the channel and components of the flow regime. These are used to frame or guide the determination of ecological water requirements.
Food web	A series of organisms related b predator–prey and consumer-resource interactions; the entirety of interrelated food chains in an ecological community.
Geomorphology	The characteristics, origin, and development of landforms.
Habitat	The area or natural environment in which an organism or population normally lives. A habitat is made up of physical factors such as soil, moisture, range of temperature and availability of light as well as biotic factors such as the availability of food and the presence of predators.

Macrophyte	A plant, especially an aquatic or marine plant, large enough to be visible to the naked eye.
Physico-chemical	Physical and chemical properties of water. Includes temperature, dissolve oxygen concentration, pH and levels of nutrients, chemical and toxicants.
Primary productivity	Production of organic compounds from carbon.
Ramsar	Convention on wetlands of international importance
Reference sites	Sites with physical and biotic characteristics similar to study sites but not under the same external pressures. For example, non-regulated rivers.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Water regime	A description of the variation of low rate in surface water or water level over time; it may also include a description of water quality.

References

ANZECC 2000, *Australian and New Zealand guidelines for fresh and marine water quality,* national water quality management strategy paper No. 4, Australian and New Zealand Environment and Conservation Council and Agricultural and Resource Management Council of Australia and New Zealand, Canberra.

Braimbridge, MJ & Malseed, BE 2007, *Ecological water requirements of the lower Ord River,* Environmental Water Report No. 4, Department of Water, Perth.

Croot, K 2002, *Designing a monitoring methodology for a large regulated river: the lower Ord River, North Western Australia,* Honours Thesis, *Department of Geology,* the University of Western Australia, Perth.

Department of Water 2009, *A strategy for managing the flow of the Ord River from Lake Argyle to Reedy Creek by operation of the Kununurra diversion dams* Department of Water and Water Corporation, Perth.

Environmental Protection Agency 2000, *Perth's coastal waters. environmental values and objectives: the position of the EPA - a working document,* Environmental Protection Authority, Perth.

Fredricks, D 2006, *Ord River Irrigation area water quality report 1998-2005*, Water and Rivers Commission, Perth.

Froend, R & Loomes, R 2004, *Approach to the determination of ecological water requirements of groundwater dependent ecosystems in Western Australia*, CEM report no. 2004–12, Centre for Ecosystem Management, Edith Cowan University, Joondalup.

Ord Irrigation Cooperative Limited 2009, *Operating strategy for licence no. SWL156287(2) issued under section 5C of the Rights in Water and Irrigation Act 1914*, Ord Irrigation Cooperative and Department of Water, Kununurra.

Robson, BJ, Burford, MA, Gehrke, PC, Revill, AT, Webster, I & Palmer, DW 2008, *Reponse of the lower Ord River and estuary to changes in flow and sediment nutrient loads*, *Water for a healthy country national research flagship,* CSIRO.

Start, AN, Wyroll, KH & Handasyde, T 2002, *Long-term riparian monitoring for the lower Ord River,* Progress report to the Water and Rivers Commission, Perth

Trayler, K, Malseed, BE & Braimbridge, MJ 2006, *Environmental values, flow related issues and objectives for the lower Ord River, Western Australia*, Environmental Water Report Series, Report No. 1, Department of Water, Perth.

WR&M 2008, *Design of an environmental water provision monitoring and assessment program for the lower Ord River*, Unpublished report by Wetland, Research and Management to the Department of Water, Perth.

Department of **Water**
168 St Georges Terrace, Perth, Western Australia
PO Box K822 Perth Western Australia 6842
Phone: 08 6364 7600
Fax: 08 6364 7601
www.water.wa.gov.au
2149 30 0611