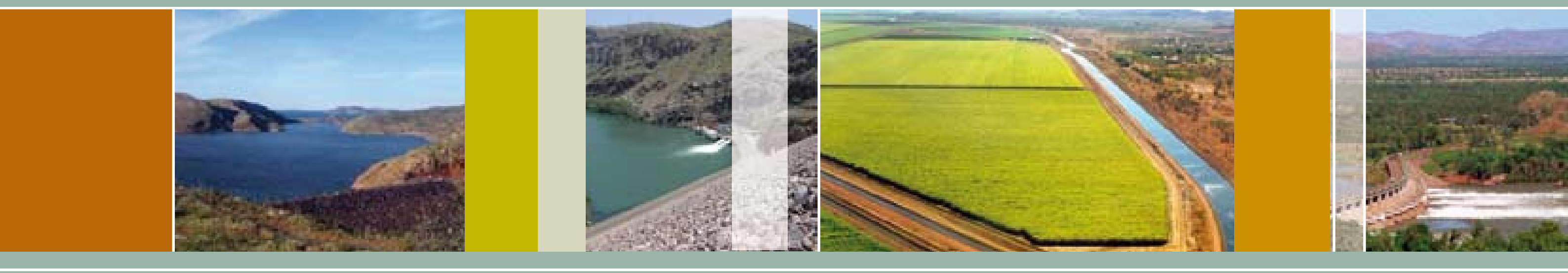
Department of Water
Government of Western Australia

Ord River Water Management Plan

DECEMBER 2006



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Department of Water
Level 4, 168 St Georges Terrace
Perth Western Australia 6000

<www.water.wa.gov.au>

Telephone +61-8-6364 7600
Facsimile +61-8-6364 7601

For more information about this report, contact
Ian Loh, Program Manager.

(08) 6364 6839

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Subject of cover photograph
Lake Argyle, Ord River Dam, Irrigation area and the Kununurra Dam.

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Preface

The Department of Water (the Department) is the lead agency for the management of water resources in Western Australia. The Department carries out this task in partnership with other government agencies, stakeholder groups and the community.

The *Rights in Water and Irrigation Act 1914 (*RIWI Act) and *the Rights in Water Irrigation Regulations (2000)* provide the legislative basis for water resource management in Western Australia. In administering the RIWI Act the Department seeks to balance the ecological needs and social expectations of water in the natural environment with society's need to use water for public water supply and commercial purposes. The objective is to provide for the sustainable development of water resources in the long-term, for the benefit of current and future generations. This involves ensuring that sufficient water is maintained in the natural environment, while providing for the responsible development and efficient use of water resources.

The Department prepares water management plans to specify how water resources are to be shared between these competing needs in particular areas. Management plans establish sustainable diversion limits for particular water resources that define the water available for use. The limits are established by ensuring that sufficient water is retained in the resource to protect water-dependent ecosystems and to meet specific social needs.

This water management plan seeks to balance the needs of the environment and development in the case of the Ord River, Western Australia.

Summary

This plan describes how the waters of the Ord River are to be shared between the needs of the riverine environment of the lower Ord, and commercial water needs of irrigation and hydro-power generation, over the next three years.

Background and purpose of the plan

The first stage of the Ord River Irrigation Project commenced in the early 1960s with the construction of the Kununurra Diversion Dam and the completion of the first serviced farmlands to the east of the Ord River (Ivanhoe Plain). Stage 1 of the Ord River Irrigation Project was established by the mid 1970s after the construction of the Ord River Dam and completion of additional serviced farmlands to the west of the River (Packsaddle Plain).

Irrigated agriculture proved marginal in the Ord River Irrigation Area (ORIA) for the first two decades of operation. The ORIA recovered slowly after the failure of cotton as a commercial crop in the mid 1970s. By the early 1990s sufficient confidence had returned in the future of the ORIA for the Western Australian (WA) and Northern Territory (NT) Governments to commence planning for the expansion of the ORIA. In 1995-96 the Ord River Dam Hydro-electric Power (ORDHP) Station was constructed to supply electricity to the Argyle Diamond Mine and the towns of Kununurra and Wyndham.

To facilitate planning for the expansion of the ORIA the Water and Rivers Commission commenced the development of a water allocation plan for the Ord River in 1997. The aim was to establish how Ord River water would be shared between the competing needs of the environment, current and future irrigation and hydro-electricity generation. A draft of an Interim Water Allocation Plan was released for public comment in May 1999. The Environmental Protection Authority (EPA) reviewed the plan and public comments received, and recommended changes to the interim environmental water provisions in December 1999. This plan responds to the recommendations of the EPA and seeks to:

- protect the riverine environment of the lower Ord River as it has adapted to the changed flow regimes since the Ord River Dam was constructed;
- provide for existing commitments to irrigation and hydro-power generation;
- guide planning for the Western Australian portion of M2 Supply Area and irrigation developments on the lower Ord River downstream of House Roof Hill;
- identify the potential for further hydro-electricity to be generated at the Ord River Dam and the Kununurra Diversion Dam; and
- indicate the potential for additional irrigation allocations to be made in the future.

The effect of regulation by the Ord River Dam

The construction of the Ord River Dam has caused major changes to the flow regime of the Ord River. Prior to its construction, the Ord River flooded regularly, inundating large areas of its floodplain once in every two to three wet seasons. Most floods were sufficiently powerful to scour the riparian vegetation from banks of the river downstream of the Kununurra Diversion Dam. Flows receded rapidly following the wet season, ceasing by June in most dry seasons, with the river reducing to a series of unconnected pools. After construction of the Ord River Dam, wet season floods have been reduced by a factor of about ten and the river has continued to flow strongly throughout the dry season. Typical flow rates have increased from about 0.0-50 m^3/sec over the driest five months of the dry season.

These changes have altered the ecology of the lower Ord River, making it more like a river from the wet tropics, rather than the dry tropics of the Kimberley region. Reductions in the size and erosive power of floods has resulted in a more stable, dense band of riparian vegetation approximately 15 m wide along the water's edge within the main river channel. The permanent dry season flows have increased aquatic habitat and encouraged larger sized fish to develop in the lower Ord River than in nearby unregulated rivers, although the range of fish species found has remained very similar.

The changes caused by the initial regulation of the Ord River are significantly larger than the changes expected from additional allocations proposed in this plan.

Key principles and approaches

Maintaining sufficient in-stream habitat for invertebrates and fish during the dry season was the primary factor used to establish environmental water provisions for the lower Ord River. This was achieved by limiting the change in measures of dry season in-stream habitat, to levels considered of low ecological risk. Measures of in-stream habitat were determined over a range of flow regimes, including the flow rates considered typical of dry season conditions since the Ord River Dam was constructed (50-60 m^3/sec). A flow regime was selected that limited occasions when in-stream habitat measures changed by more than 20 per cent, relative to the habitat measures present at flow rates of 50-60 m^3/sec.

Water released from Lake Argyle to generate hydro-electricity can also be diverted for irrigation at Lake Kununurra or used to contribute to environmental flows in the lower Ord River. However, when the hydro-electricity releases exceed the downstream water demands, the excess hydro-electricity releases become an additional draw on Lake Argyle and reduce water availability in subsequent years. The excess of water demands for hydro-electricity over irrigation and environmental water demands, especially during the wet season, has been a central consideration in developing the allocations of this plan.

Water restrictions are introduced when water storage levels reach critical levels during times of drought. These are necessary to avoid even more severe restrictions in subsequent years if the drought persists. To protect the reliability of existing and new allocations, restrictions need to be introduced at progressively higher storage levels as more of the available water resource is allocated. The plan highlights the need to progressively increase the water level criteria in Lake Argyle at which constraints on the generation of hydro-electricity are required, as additional licensed entitlements are granted and additional hydro-electricity production allowed.

The plan has been released at this time to guide the staged development of the Western Australian portion of the M2 Supply Area and address the growing demand for hydro-electricity generation in the region. It does not attempt to resolve the competition between hydro-electricity generation and additional allocations to provide for expansion of the M2 Supply Area into the Northern Territory.

Water allocations

The waters of the Ord River are to be managed and shared in the following ways.

Protection of the riverine environment of the lower Ord River

Essential in-stream ecological processes and the biodiversity of the lower Ord River, that have characterised the riverine environment since the river has been regulated by the Ord River Dam, are to be protected by the following flow regime:

- When water levels in Lake Argyle are above 76 m AHD (expected 95 per cent of the time), the lower Ord River is to be maintained at an average monthly flow rate of at least:
    - 45 m^3/sec from the Dunham River confluence to House Roof Hill[1], and
    - 40 m^3/sec downstream of House Roof Hill
- During drought periods when water levels in Lake Argyle are less than 76 m AHD (expected 5 per cent of the time)[2]
    - 35 m^3/sec from the Dunham River confluence and House Roof Hill, and
    - 30 m^3/sec downstream of House Roof Hill
- No significant increase is to be permitted in the regulation of the Dunham River tributary.

Responsibility for maintaining this environmental water provision has been assigned to the Water Corporation, under conditions of their *Rights in Water and Irrigation Act 1914* (RIWI Act) licence that specifies how the Ord River Dam and Kununurra Diversion Dam are to be operated.

[1] House Roof Hill is approximately 58 km downstream of the Kununurra Diversion Dam.
[2] Restrictions on irrigation diversions and hydro-power generation will also apply during these drought periods.

Hydro-electric power provisions at the Ord River Dam

Water Corporation's Ord River Dam RiWI Act licence also provides for the release of water through Pacific Hydro Pty Ltd's Ord River Dam Power Station for the generation of hydro-electricity. Currently, releases are made in accord with the existing water release principles of the 1994 Water Supply Agreement (WSA) between Pacific Hydro Pty Ltd and the Water Authority of WA.[3] New release rules have been developed to protect the reliability of Stage 1 allocations while the power station's annual electrical energy load exceeds the current minimum provision of 210 GWhrs/yr, and before new generating capacity is constructed in the region.[4] These changes are being negotiated with the company in accord with the provisions of the *Ord River Hydro Energy Project Agreement Act 1994* and will be implemented through revisions to Water Corporation's licence. Release rules will be updated as additional water entitlements are granted and Stage 2 irrigated areas developed.

Hydro-electric power provisions at the Kununurra Diversion Dam

The Department of Water (the Department) will support proposals to generate hydro-electricity at the Kununurra Diversion Dam. The water available for electricity generation will be restricted to flows being released through the dam to meet the downstream Environmental Water Provisions (EWP) flow regime or to discharge surplus inflows to the dam. This run of river provision excludes specific releases being made from either Lake Argyle or Lake Kununurra, for electricity generation at the Kununurra Diversion Dam. Consequently, the electricity able to be generated is directly dependent on the EWP regime for the lower Ord River. Under the interim EWP regime of this plan, an average of at least 50 GWhrs/yr, depending on the design of the station, is potentially available. While additional electricity can be generated while water is not being diverted for the M2 Supply Area, the Department will not guarantee a specified quantity of water for electricity generation at the Kununurra Diversion Dam.

Provisions for a fishway at the Kununurra Diversion Dam

The Department will provide water to support a fishway at the Kununurra Diversion Dam, provided the required flow is minimised and does not significantly reduce the hydro-electricity potential at the dam. Proposals requiring a continuous flow rate of more than 1 m^3/sec would not be supported.

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3 The Water Authority of WA's functions are now undertaken by the Water Corporation (water service provision) and the Department of Water (water resources management).

4 New electricity generation capacity is likely to be established to meet growing electricity demand as Argyle Diamond Mine mining proceeds underground. New capacity, using renewable energy sources, is expected to be significantly cheaper and environmentally preferable to relying on additional use of the existing diesel fired plant at Argyle Diamond Mine.

Sustainable diversion limit from Lake Kununurra to Tarrara Bar

The sustainable diversion limit for the Ord River between Lake Kununurra and Tarrara Bar[5] is 750 GL/yr. This diversion limit provides 350 GL/yr for use on developed Stage 1 land and for minor demand growth in Stage 1 areas. The diversion limit also provides for an initial allocation of 400 GL/yr for future demands in new areas. Future demands are expected to grow in increments, especially as the M2 Channel Supply Area (M2 Supply Area) is to be developed in stages, and new demands are not expected to exceed 400 GL/yr for at least three years. Further specification of these allocations and how water entitlements would be granted from these allocations is described below:

- The 350 GL/yr allocation for Stage 1 areas has two components. The first 250 GL/yr is based on an expected annual reliability of 95 per cent, and provides for historic use, corrected for required efficiency gains. The second 100 GL/yr is based on an expected annual reliability of 90 per cent, and provides for demand growth in Stage 1 areas.[6]
- The initial 400 GL/year allocation for future demand is based on an expected annual reliability of 95 per cent. This allocation is more than sufficient to irrigate 14,800 ha of sugarcane (on 16,000 ha of farmland) given the evapo-transpiration and rainfall conditions expected in the M2 Supply Area. Hence the allocation would support the staged development of at least 16,000 ha of serviced farmland in the M2 Supply Area (53 per cent of the planned total of 30,064 ha). The allocation would support a larger farmland development if the area committed to growing sugarcane were reduced and replaced by a greater area of other crops with lower crop water requirements.

Applications for water entitlements[7] under this allocation will be required when each new stage of the M2 Supply Area is to proceed or new demand develops. New water entitlements will be granted based on the area to be supplied, and the crop types or type of use planned. The entitlements could be issued with an expected annual reliability of up to 95 per cent, depending on the reliability sought and the crop types or use planned. Efficient water management practices will be expected and will be a condition of granting the new entitlements. In the M2 Supply Area, this means the use of best irrigation practices, including automated control and scheduling systems for water distribution and on-farm water recycling facilities.

As provided for under the *Ord River Hydro Energy Project Agreement Act 1994,* Government will consult with Pacific Hydro Pty Ltd when an application for new water entitlements from the initial 400 GL/yr allocation is received. New water release rules for the Ord River Dam Power Station will be developed to be compatible with the sum of existing and new water entitlements, if the application were granted (in whole or

5 Tarrara Bar is located approximately 33 km downstream of the Kununurra Diversion Dam.

6 When the allocation was initially made, sugarcane plantations in Stage 1 areas were planned to increase from approximately 3,800 ha to 6,000 ha.

7 The application, assessment and procedures involved in granting water entitlements are specified in the licensing provisions of the Rights in Water and Irrigation Act 1914.

part). Final water release rules will be negotiated with Pacific Hydro Pty Ltd with the aim of ensuring sufficient water is available for the staged development of the M2 Supply Area, while protecting the commercial interests of the company. Current studies indicate that, if the initial 400 GL/yr allocation were all granted as entitlements (at 95 per cent reliability), compatible water release rules can be developed that would not significantly impact the company's commercial interests. This was found to be the case even when the power demand on the station was assumed to be at or near the maximum output of the station.[8].

Sustainable diversion limit downstream of House Roof Hill

The sustainable diversion limit from the lower Ord River, downstream of House Roof Hill, is 115 GL/year. This allocation has an expected annual reliability of at least 95 per cent (similar to the environmental water provision reliability) and is planned to supply future developments in the Mantinea Plain and Carlton Plain areas. Water entitlements will be granted up to the allocation limit, depending on the application(s) made, the areas to be supplied, and the uses and crop types proposed. The applicant(s) and irrigators will be required to establish efficient water distribution infrastructure and on-farm watering equipment and implement best irrigation practices.

Effects of additional allocations

The plan's interim EWP regime is designed to protect the environmental and social values of the lower Ord River under post-regulation conditions. Minor changes to in-stream habitat and riparian vegetation are likely when the additional allocations of this plan are implemented. However, these changes are expected to be small relative to changes caused by natural variations in wet season peak flows of the lower Ord River. These wet season peak flows are generated from the (effectively unregulated) catchment downstream of the Ord River Dam. Aquatic fauna should readily adapt to minor changes in river habitats and water quality of the lower Ord River is not expected to deteriorate under the EWP regime. More efficient irrigation practices in Stage 1 areas should reduce the biological loadings on the lower Ord River in the future. No significant changes are expected to the range of water levels of Lakes Kununurra and Argyle, or in the salinities of estuarine water in Cambridge Gulf. While the flood regime of the lower Ord River was substantially reduced by the construction of the Ord River Dam, the additional diversions allowed under this plan will not result in any significant further reduction in the flood regime. Consequently, no measurable impacts are expected on the Ramsar wetland values of the Parry's Lagoon Nature Reserve, the Ord floodplain, Lake Kununurra or Lake Argyle as a result of the provisions in this plan.

[8] Reservoir simulations have indicated that by maintaining the environmental water provisions in the lower Ord River, and supplying an average irrigation entitlement of 760 GL/yr in 95 per cent of years (Stage 1 and M2 Supply Areas), an average of over 235 GWhrs/yr of electrical energy could be generated.

Development and revision of the plan

Consultation during development

Development of this plan commenced in 2000 to respond to the EPA advice on the 1999 Interim Plan. It evolved over the subsequent five years in response to changing circumstances and water and electricity demand pressures. Consultations over the plan commenced with the Kununurra community in 2000 and continued with key stakeholders over specific aspects of the plan in the following years. Specific stakeholder consultations have included negotiations with:

- Ord Irrigation Co-operative and Water Corporation over allocation and licensing conditions;
- Pacific Hydro Ltd over water release rules for the ORDHP Station; and
- the Department of Industry and Resources (formally known has the Department of Resources Development) over allocations for Stage 2 Supply Area.

Over the past six years local efforts in Kununurra have been successful in improving co-ordination and knowledge about water issues, and building capacity to improve water resource management in Stage 1 areas and management of the Ord River system. These efforts have helped progress implementation of the Kununurra community's 2000 Ord Land and Water Management Plan (OLWMP) and complemented management objectives of this plan. The ongoing commitment of local stakeholders to implement OLWMP strategies is contributing significantly to improving water management in Stage 1 areas. Considerable effort has also been made to engage Indigenous people in water and natural resource management and further engagement is expected to consolidate their involvement.

Updating the plan

Work is well advanced on updating the hydrology of the Ord River catchment and completing a comprehensive assessment of Ecological Water Requirements (EWR) for the lower Ord River. This work will be used to inform a review of this plan over the next two to three years.

As part of developing this updated plan it is intended to:

- assess the effects of the new EWR for the lower Ord River on the water available for irrigation and hydro-electricity generation;
- hold stakeholder consultations to consider allocation options and assess their merits against environmental, social and economic criteria;
- establish updated (fine tuned) Environmental Water Provisions (EWP) for the lower Ord River, and
- resolve the balance between hydro-electricity generation and additional water available for further irrigation expansion.

1 Introduction

1.1 Background

1.1.1 The Ord River Irrigation Project

Irrigation commenced in the Ord River Irrigation District (the District) in 1963. Construction of the Kununurra Diversion Dam and M1 Channel distribution system enabled the first water to be diverted from the Ord River in May 1963 and supplied to irrigation farmland on the black soils of the Ord River floodplain (the Ivanhoe Plain). The Kununurra Diversion Dam is a 20 m high structure that forms Lake Kununurra, holding water in the Ord River watercourse for approximately 50 km upstream. Lake Kununurra has a maximum storage of 101 GL (to the top of dam's gates at 41.76 m AHD) and enables water to be diverted to the current and planned irrigation areas of the Ord River Irrigation Project.

The Ord River Dam is located approximately 60 km upstream in the Carr Boyd Ranges, and provides the storage necessary to ensure a reliable water supply to the District. Construction of the Ord River Dam commenced in 1969, and the dam began to store water in Lake Argyle, the reservoir formed by the dam, in November 1971. Water levels in Lake Argyle reached the dam spillway (86.2 m AHD, storage 5,800 GL) for the first time during the 1973-74 wet season. Stage 1[9] of the Ord River Irrigation Project was effectively established in 1973, when construction of water distribution and drainage infrastructure, and serviced farmland to the west of the Ord River (Packsaddle Plain) was completed. Further aspects of the initial establishment and early years of operations of the Ord River Irrigation Project are given in Appendix 1.

Figure 1 shows the location of the main features of Ord River Irrigation Project, and indicates the existing (Stage 1) and potential (Stage 2) irrigation supply areas. Approximately a third of the Stage 2 areas occur in the Northern Territory (NT).

The Stage 1 irrigation infrastructure of the Ord River Irrigation Project has been successfully established, however the financial viability of irrigated agriculture in the District proved problematic for the first 25 years. Failure of cotton crops in the mid 1970s (Le Page, 1986; Powell, 1998) saw many irrigators leave the District and plans to release additional areas of serviced farmland were delayed. Areas under irrigation remained low for many years and did not recover until the early 1990s, after new horticultural crops were introduced to the District. As these could be grown

9 To distinguish new proposals from existing developments, Stage 1 of the Ord River Irrigation Project is defined in this plan to include all infrastructure, existing at September 2004, that stores, diverts or transports water from the Ord River or drains water from farmland in the Ord River Irrigation District. This definition includes the Ord River Dam and water infrastructure on Packsaddle Plain Supply Area, although the 1959 project proposal considered these developments as part of the second stage of an overall four stage project (see Appendix 1).

out of season from traditional growing areas in southern Australia, they attracted high prices at market, and offset some of the high costs of operation, caused by the remoteness of the District. With confidence in the future of the District returning in the early 1990s, areas under irrigation increased and continued to grow during the decade. By 2000, the area of developed farmland[10] with potential to access Ord River water had grown to about 15,000 ha and is referred to as the Stage 1 developed areas for the purposes of this plan. Between 11,000 and 12,200 ha has been irrigated in recent years.

The Ord River Dam was designed to enable a hydro-electric power station to be constructed when there was sufficient electricity demand to justify the additional investment. Investigations during 1994 led Pacific Hydro Pty Ltd to construct a 30 MW hydro-electric power station at the Ord River Dam and transmission lines to supply most of the electricity demand of Kununurra and Wyndham and the Argyle Diamond Mine. Construction commenced in 1995 and the station became fully operational by 1996. As part of the power station development, the base of the Ord River Dam spillway was raised 6 m, to increase the electrical energy able to be supplied by the station. This increased the base of the spillway to 91.2 m AHD and the storage of Lake Argyle at this level to 10,700 GL.

1.2 Ord River water allocation planning

1.2.1 Need for a water allocation plan

In the mid 1990s, the Western Australian (WA) and Northern Territory (NT) Governments commenced planning to establish new irrigation supply areas as originally conceived in the Ord River Irrigation Project. Pressures to open up additional areas for irrigation had been growing from the early 1990s as more of the available Stage 1 areas came under production.

Unlike the initial construction phase of the Ord River Irrigation Project, a range of approvals are now required before new irrigation supply areas can proceed. The major approvals involve assessment of environmental impact, land access, especially Native Title and Aboriginal heritage aspects, and water resource access and management. Water allocation planning was required to address the water resource management aspects raised by establishing new irrigation supply areas.

At the same time that the WA and NT Governments were planning for the expansion of irrigation on the Ord, the Governments were also progressively introducing water reforms that they had committed to under the Council of Australian Governments (COAG) 1994 Water Reform Framework Agreement. The 1994 water reforms centred on ensuring that explicit water provisions were made for the environment, that rights to use water were more clearly defined and that these rights could be traded to encourage higher valued uses of water. The current National Water

[10] Some small land releases and sub-divisions occurred after the Packsaddle area was completed in 1973.

Initiative builds on these reforms by strengthening requirements to complete water allocation plans and define water entitlements in a consistent way across jurisdictions.

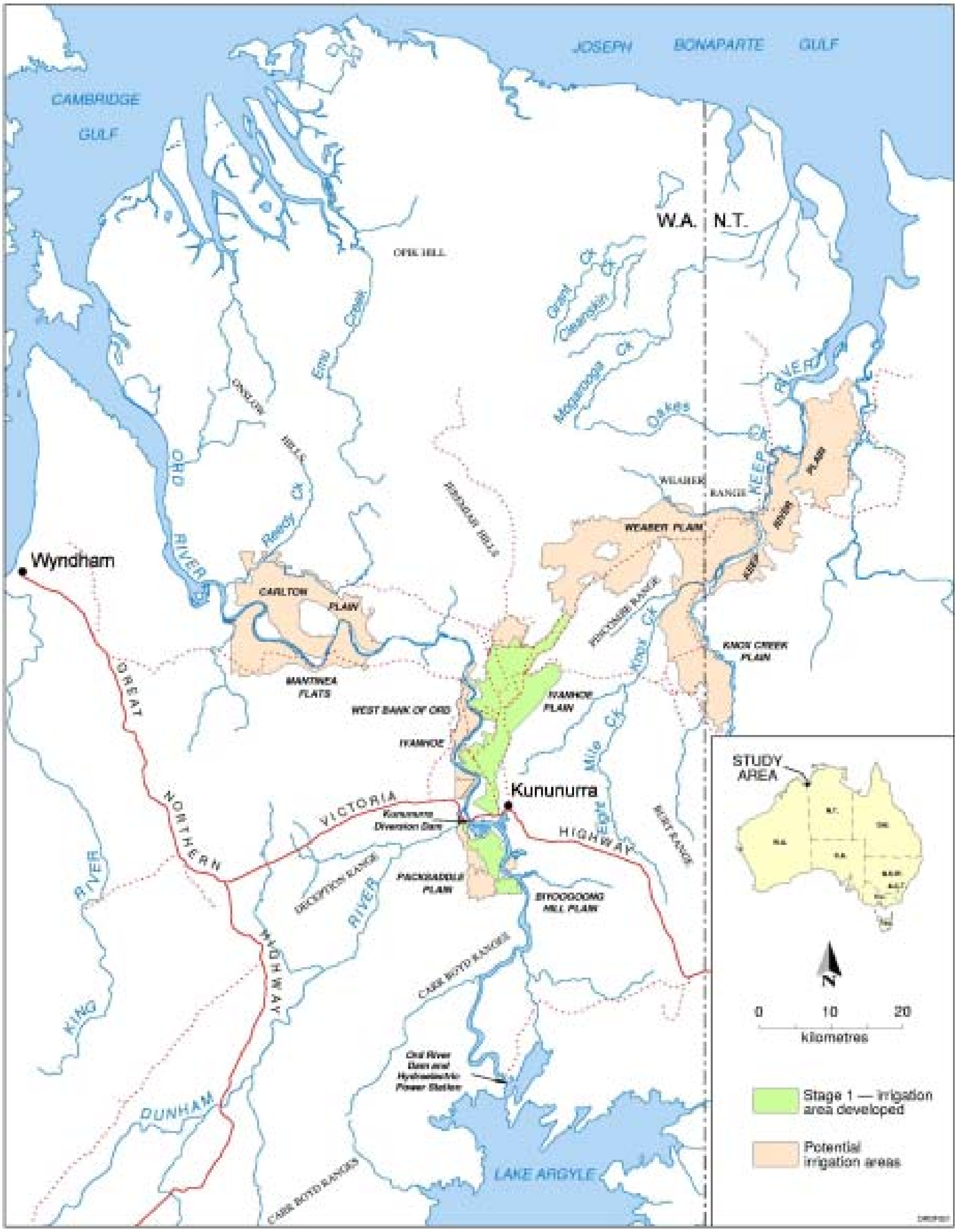


Figure 1: Location map showing key features of the Ord River Irrigation Project

1.2.2 The 1999 Interim Water Allocation Plan

The Water and Rivers Commission (the Commission), now also known as the Department of Water, commenced water allocation planning in 1997 to determine how the waters of the Ord River should be shared between competing water needs. This involved consideration of the needs of water-dependent ecosystems of the lower Ord River, the socio-cultural expectations the community had of the river, the resource commitments already made, and balancing these against future irrigation and hydro-electricity demands. A draft Interim Water Allocation Plan for the Ord River was released for public review in May 1999 (WRC, 1999b), the main elements of which are outlined in Appendix 2.

The 1999 draft plan proposed to maintain the 20th percentile of pre-dam flows in the lower Ord River, allocate approximately 1,240 GL/yr for current and future irrigation use, and 110 GWhrs/yr for the long term hydro-electricity demand of the East Kimberley towns of Kununurra and Wyndham. This left approximately 265 GL/yr unallocated, to be allocated later when more was known about the Ecological Water Requirements (EWR) of the lower Ord River, socio-cultural water needs and the crop water demand of sugarcane in the area.

The Environmental Protection Authority (EPA) reviewed the draft plan and public comment received, and provided advice to the Commission on the proposed interim Environmental Water Provisions (EWP) of the plan in December 1999 (EPA, 1999, and Appendix 2).

The EPA considered that *"… the interim and final EWP should be based on protecting environmental values, which are sustainable under post-dam flows".* Since the Ord River Dam was completed in 1972, dry season flows in the lower Ord River had increased significantly. Flows had become continuous throughout the year and the large flood storage capacity of Lake Argyle had greatly reduced the frequency of downstream flooding during the wet season. A modified riverine ecology had established along the lower Ord River in response to this altered flow regime. The EPA considered that a revised EWP regime should be developed that would protect this modified riverine environment.

1.2.3 Revising the 1999 draft Environmental Water Provisions

A major re-assessment of the allocations in the 1999 draft plan was necessary to adequately respond to the EPA advice (EPA, 1999). The Commission recognised that difficult judgements would be required to establish a revised EWP regime that protected the modified riverine environment, while also providing for future irrigation expansion.

When embarking on this task (early in 2000), limited information was available on the ecology of the lower Ord River. The Commission established a scientific panel in

April 2000, with expertise in tropical river ecosystems, to provide the best possible scientific knowledge to guide the revision of the EWP regime[11].

The Scientific Panel reported to the Commission in June 2000 (WRC, 2000a) and proposed an interim approach to establish an EWP regime that met the new objective. The June 2000 advice is summarised in Section 3.3 and guided the development of the revised EWP regime, adopted in this plan. Scientific Panel members have continued to advise the Commission periodically during the preparation of this plan.

Knowledge of the riverine ecology of the lower Ord River has improved considerably since 2000. The Department of Water (the Department) has recently published a review of research and investigation studies related to the aquatic ecosystems of the lower Ord River (Trayler *et al.,* 2006). The review summarises current knowledge of the river's ecosystems and provides the basis for a comprehensive assessment of EWR for the lower Ord River. The comprehensive EWR will be used to update the lower Ord River EWP and contribute to revision of this plan.

1.2.4 Hydro-electricity demands and staged development of the M2 Supply Area

Significant changes in the projections of future demands on the Ord River resource have occurred since 1999. These changes have resulted from changes in the way Stage 2 irrigation developments may occur, and uncertainties over the projected electricity demand of the Argyle Diamond Mine and hence the Ord River Dam Hydro-electric Power (ORDHP) Station.

In 2000, the electricity demand at the Argyle Diamond Mine was expected to decline soon after 2003 when the alluvial deposits were expected to be fully mined. When proposals to extend the mine life beyond 2003 were first discussed, future power demands on the Power Station were expected to remain around the then current demand of 210 GWhrs/yr. A series of progressively higher demands were projected from 2002 onwards, as plans to extend the life of the mine became more definitive. Demands of 320 GWhrs/yr and higher became a real possibility in 2004, when Rio Tinto, owners of the mine, committed to continue mining to at least 2007 and embark on a full scale investigation of continuing a deep underground operation for a further ten or more years. The likelihood that high future demands on the station would be realised was increased in December 2005, when Rio Tinto announced their intention to proceed with the underground operation.

The magnitude and timing of new irrigation demands has also changed since 1999. The major change occurred in December 2001, when a joint venture of Wesfarmers, Marubeni and the Water Corporation withdrew from establishing 29,000 ha of sugarcane on 32,000 ha of new irrigated farmland, known as the M2 Supply Area.

[11] The EPA had recommended that a scientific panel be established for this purpose.

When the withdrawal was announced, the WA and NT Governments restated their commitment to establishing new areas of the Ord River Irrigation Project. The Minister for State Development accepted responsibility as caretaker proponent for M2 Supply Area development, while issues of Native Title and water allocation were progressed.

In October 2006, the WA Government sought private sector interest in developing between 7,000 ha and 16,000 ha of irrigation serviced farmland in the M2 Supply Area within Western Australia. This decision follows the signing of the Ord Final Agreement between the Government and the Miriuwung and Gajerrong people in October 2005. The Ord Final Agreement resolved Native Title and Aboriginal heritage issues over land in Western Australia planned to become irrigated farmland under Stage 2 developments of the Ord River Irrigation Project. In particular the Ord Final Agreement enabled planning to proceed on developing the Western Australian portion of the M2 Supply Area in WA.

As the M2 Supply Area is to be developed in stages, this plan has focused on considering irrigation allocations for the WA portion of the M2 Supply Area. Further allocations can be made at a later date when Native Title and other issues are resolved in the NT and future demands on the Ord River are clearer.

1.3 Purpose of this plan

Given the above background, the purpose of this plan is to specify how the waters of the Ord River are to be shared between the competing needs of the environment, current and future irrigation and hydro-electricity generation over the next three years.

The plan is intended to:

- protect the riverine environment of the lower Ord River as it has adapted to the changed flow regimes since the Ord River Dam was constructed;
- provide for existing commitments to irrigation and hydro-power generation;
- guide planning for the WA portion of M2 Supply Area and irrigation developments on the lower Ord River downstream of House Roof Hill;
- identify the potential for further hydro-electricity to be generated at the Ord River Dam and the Kununurra Diversion Dam; and
- indicate the potential for additional irrigation allocations to be made in the future.

1.4 Aims

The Plan aims to:

- specify interim environmental provisions for the lower Ord River;
- determine sustainable diversion limits from the Ord River below Lake Argyle;

- specify interim allocations for current and proposed irrigation use and power generation;
- describe the environmental effects of the proposed allocations on the flow regime of the lower Ord and Ramsar wetlands in the area;
- ensure current irrigation practices are improved so that risks to the lower Ord environment and agricultural production are reduced, and water use efficiency is improved; and
- outline how water allocations and management responsibilities will be implemented through the licensing provisions of the *Rights in Water and Irrigation Act 1914 (*RIWI Act*)*.

1.5 Updating the plan

Work has already commenced on updating aspects of the plan with an expected revision within the next three years. The revised plan is intended to:

- reflect requirements of water allocation plans envisaged under the National Water Initiative;
- be based on updated studies of the Ord River catchment and comprehensive assessments of the EWR of the lower Ord River;
- establish updated EWP for the lower Ord River, after public consultation on the implications of different allocation options; and
- resolve how any additional water will be allocated between the competing needs of hydro-electricity generation and irrigation expansion into the NT.

1.6 Layout of document

The following structure has been adopted in describing the development of this plan.

Section 2 describes the riverine environment of the lower Ord River and how it has been changed since regulation of the Ord River Dam.

Sections 3 and 4 describe the development of EWR and EWP for the lower Ord River.

The commercial demands on the Ord River water resource are presented in Section 5, and determining the water available to meet these demands described in Section 6.

The Sustainable Diversion limits and allocation strategy of the plan are summarised in Section 7. Section 8 explains the way the plan's allocations are to be managed through the licensing provisions of the RIWI Act.

The environmental effects of further allocations, not previously covered in Sections 3 and 4, are presented in Section 9.

Section 10 outlines actions commenced to update this plan.

2 The lower Ord River

Figure 2 shows the Ord River, between the Kununurra Diversion Dam and The Rocks, a distance of approximately 94 km downstream. Termed the lower Ord River in this plan, the reach extends from the point of lowest regulation (Kununurra Diversion Dam) to where the river becomes estuarine and fully tidal. Also shown are the main tributaries that join the lower Ord River downstream of the Kununurra Diversion Dam. The most significant of these is the Dunham River that joins 0.4 km downstream of the Kununurra Diversion Dam.

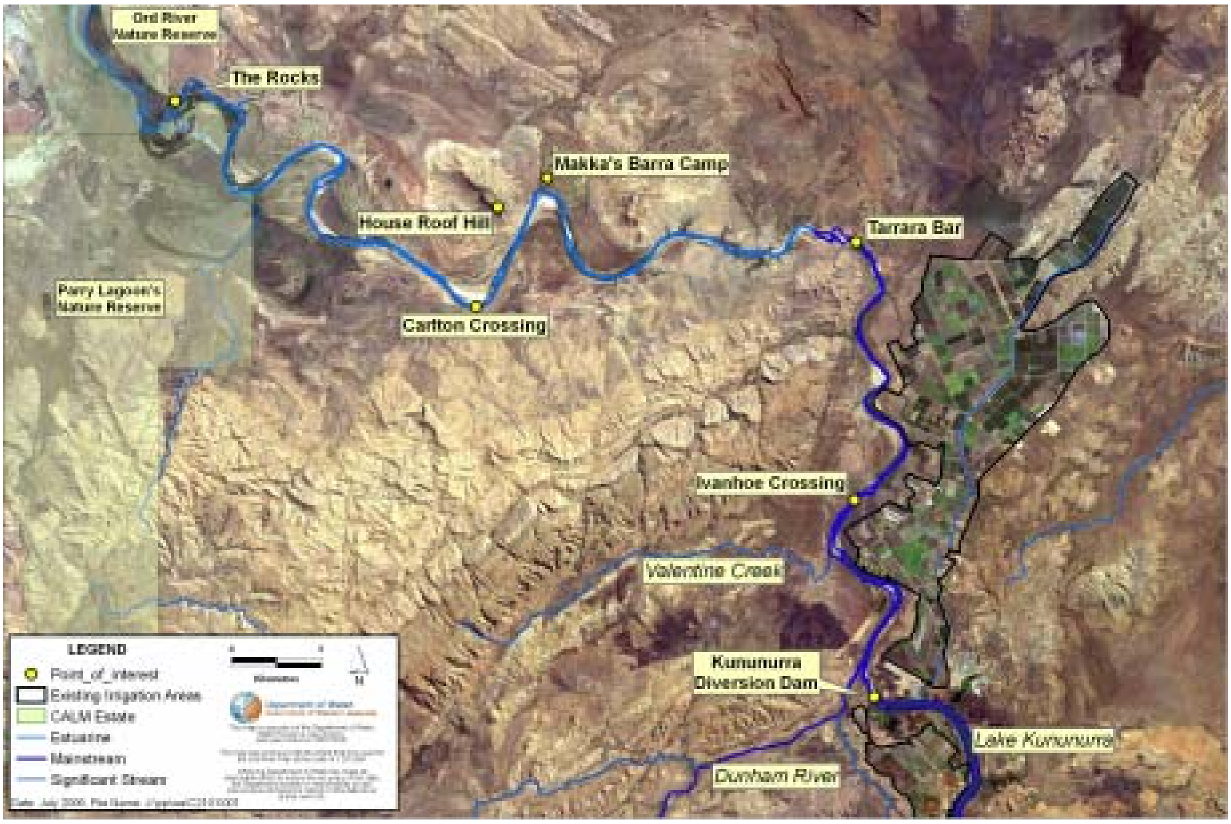


Figure 2 Map of the lower Ord River and current irrigated areas

The lower Ord River is a dynamic riverine ecosystem, shaped by the flows it experiences and the catchment management practices. The river environment has been substantially modified by changes to the hydrology of the river following the construction of the Ord and Kununurra Diversion Dams. Although regulated for over 30 years, important elements of the riverine environment are considered to still be adapting to changes caused by the construction of the Ord River Dam.

Subsequent sections describe the hydrology of the lower Ord River under pre- and post-regulation conditions and outline the consequent changes to the riverine ecosystem. To provide regional context the climatic and physiographic characteristics of the Ord River Basin are presented in the following sections.

2.1 Ord River Basin

The Ord River Basin lies between latitude 15 and 19 degrees south and drains an area of 55,100 km^2 from the Durack Ranges in the west, the Great Antrim Plateau in the south, Cambridge Gulf to the east and the Timor Sea to the north. Approximately 20 per cent drains from the NT. The climate is semi arid to arid monsoonal with two distinct seasons: a warm, dry season and a hot, wet season. No month has a mean maximum temperature below 30 °C and summer months approach average maximum temperatures of 40 °C. Annual rainfall decreases from about 800 mm/yr near the coast to 450 mm/yr inland. Annual pan evaporation is close to 3,000 mm over most of the basin.

The wet season occurs between November and March, but rains can commence in October and extend into April in some years. Rainfall is generated from either local thunderstorms or large scale tropical depressions. The tropical depressions are often remnants of cyclones that form over the Timor Sea and move inland over the Ord River Basin. Rainfall can be intense particularly in the January-February period when the risk of cyclones is greatest. During the dry season (usually from April to October) rainfalls are light and sporadic. It is common for no rain to fall for several consecutive months during the dry season, especially between June and September.

The main rivers, catchments and annual rainfall of the Ord River Basin can been seen in Figure 3. Further details on the climate, physiography, vegetation and hydrologic characteristics of the catchment are available from previous reports (WRC, 1999a; WRC, 2001).

2.2 Environmental attributes of the lower Ord River

In 2000, the Scientific Panel (see Section 1.2.3) considered the following attributes were the main features of the lower Ord River environment likely to be affected by future changes in the flow regime downstream of the Kununurra Diversion Dam:

- channel dynamics and sedimentation;
- aquatic and riparian vegetation;
- invertebrates and fish assemblages;
- waterbirds;
- ecological processes; and
- water quality.

These environmental attributes are described in the context of the pre- and post-regulation flow regimes of the Lower Ord River in Section 2.3 and Section 2.4 respectively.

The particular environmental values of Ramsar wetlands associated with the Ord River and Cambridge Gulf (the receiving water body) are described in Section 2.5.

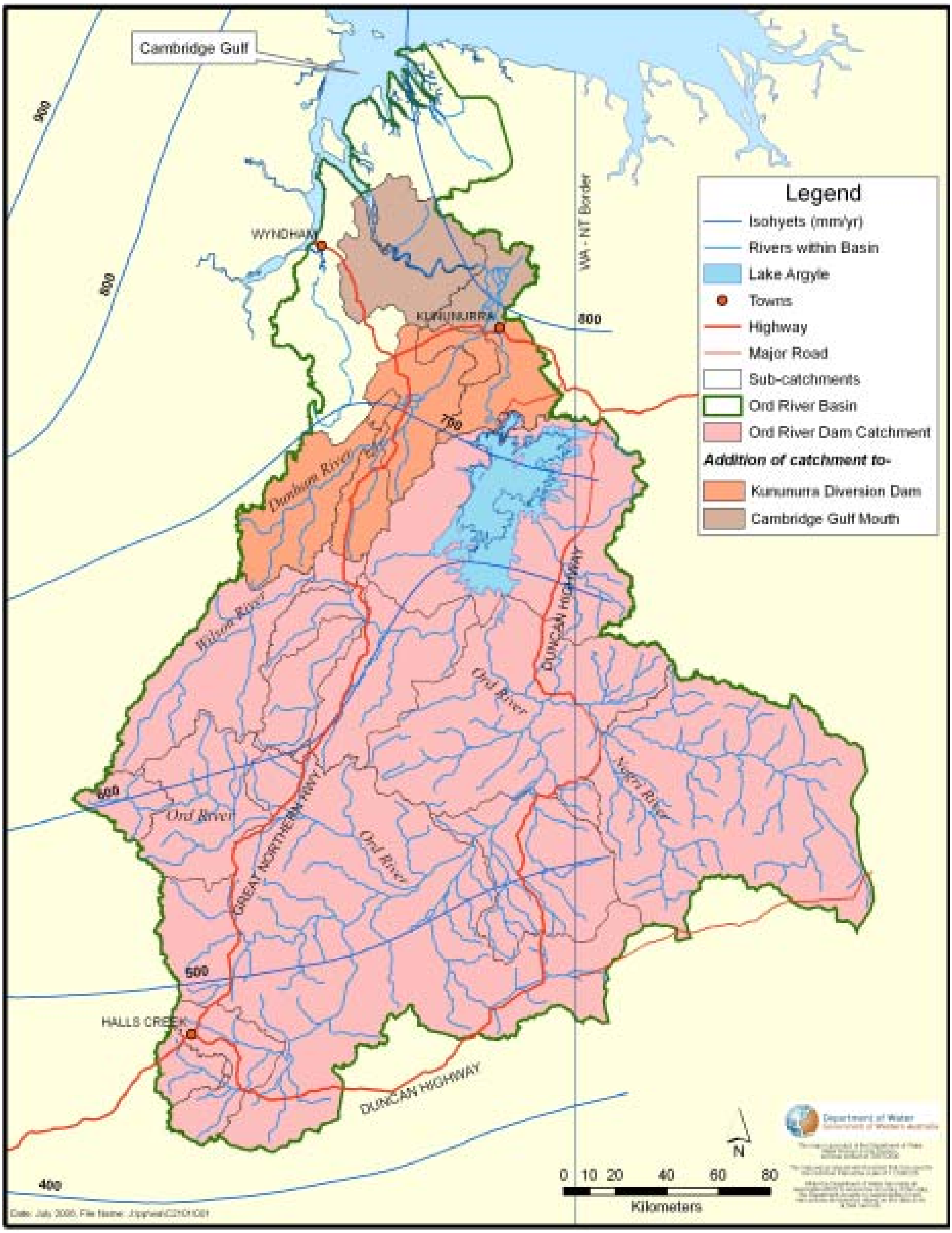


Figure 3 The Ord River Basin, showing rainfall isohyets and the main sub-catchments

2.3 The Ord River before regulation

2.3.1 Hydrology

Variation of stream flow along the lower Ord River

Table 1 presents estimates of pre-regulation mean and median annual flows in the Ord River at the Ord River Dam site and at important downstream locations to Cambridge Gulf. Over 85 per cent of the total flow to Cambridge Gulf is generated from the catchment upstream of the Ord River Dam. The Dunham River contributes the majority of the additional input, approximately 8 per cent. Flows from the catchment between the dams are approximately 2 per cent and from the local creeks downstream of the Dunham River contribute the remaining input of approximately 3 per cent. Average stream flow per unit area (or runoff) varies from 65 mm in the drier parts of the catchment (e.g. the Negri River catchment) to about 110 mm in the higher rainfall parts of the catchment, especially the Dunham River and adjacent tributaries.

Table 1 Pre-regulation average annual flows along the lower Ord River

Location on the Ord River	Catchment Area (km2)	Mean Stream flow (GL/yr) 1	Median Stream flow (GL/yr)
At the Ord River Dam site (ORD)	46,100	3,980	3,030
At the Kununurra Division Dam (KDD)	47,100	4,070	3,100
Just downstream of the Dunham River confluence	51,300	4,420	3,390
At Tarrara Bar	51,790	4,480	3,410
At Carlton Crossing	52,020	4,500	3,430
At The Rocks below Reedy Creeks	52,800	4,560	3,480
At Cambridge Gulf mouth	53,800	4,630	3,530

[1] Water year – November to October

Annual and seasonal variability

Prior to the construction of the dams, Ord River flows were highly seasonal and very variable. Table 2 summarises the annual variability and contrasts the wet and dry season flow volumes. Large flow volumes occur in wet seasons when broad scale monsoonal depressions, cyclones or their remnants cause intense and widespread rainfall over significant portions of the catchment. While widespread rainfall often occurs more than once in most wet seasons, rainfall can be limited to local thunderstorm activity in some wet seasons. Ord River stream flow is generally low in these dry wet seasons. In the driest 10 per cent of years, stream flow is less than one quarter of the average or one third of the median. In the wettest 10 per cent of years, stream flow is twice the average and almost three times the median.

The seasonal variation is also very high. In typical years, over 80 per cent of the annual stream flow occurs between January and March (Figure 4).Stream flow volumes reduce rapidly after the end of the wet season as soils are shallow and base flow limited. Some stream flow can be generated in the early months of the dry season when late rains occur. Typically however, little or no flow occurs between May to October.

Table 2 Annual and seasonal Ord River flows just below the Dunham River – Pre-regulation (1906-07 to 1991-92)

Statistic	Water Year Nov-Oct GL	Wet Season Nov -Mar GL	Dry Season* Apr-Oct GL	5 months av. flow –Jun to Oct - m^3/sec
Mean	4,420	4,170	250	1.8
Historic maximum	14,560	12,660	2,030	17.7
90th percentile	8,850	8,470	610	5.9
75th percentile	6,250	6,120	270	1.6
50th percentile	3,390	3,210	140	0.6
25th percentile	1,970	1,800	50	0.2
10th percentile	1,020	830	20	0.0
5th percentile	680	460	10	0.0
Historic minimum	225	220	5	0.0

Note: The dry season percentile does not necessarily equal the difference between the annual and wet season percentile

Flood response

Small creeks and tributaries of the Ord River respond quickly to rainfall during the wet season. Local flash flooding is common and is a result of local rainfall of high intensity, coupled with the shallow soils and steep terrain in parts of the catchment. When the areal extent of intense rainfall is lar ge, the main river responds quickly and generates large flood flows that peak within 48 hours of the rainfall event. The Ord River, prior to regulation, recorded a peak flow rate of 30,800 m^3/sec in 1956. This is comparable with the largest recorded flow rates of any river in the world with an equivalent catchment area (Rodgers and Ruprecht, 2000). Figure 5 shows typical pre-regulation daily peak flows of the Ord River at the dam site during the highest flow periods of a dry wet season (1961) and an average wet season (1962).

2.3.2 Low flow response

Upstream of tidal influences, the river dried to a series of isolated pools in the deeper parts of the channel during the dry season. Pools commonly formed on the outside of meander bends. Hydraulic modelling of the effects of the large tidal range in Cambridge Gulf (7 m at spring tide) indicated that at low flows of 2 m^3/sec or less, salt water would have extended upstream of Carlton Crossing at spring tides.

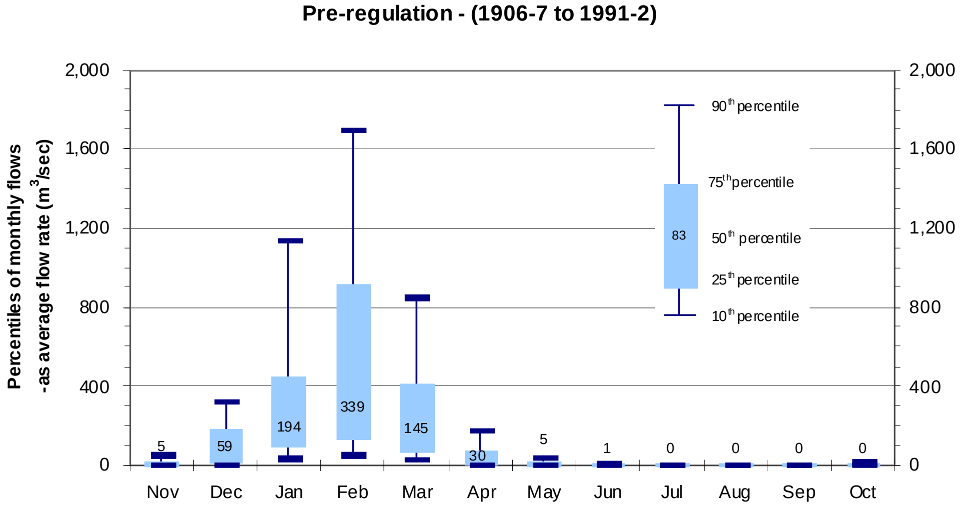


Figure 4 Percentiles of Ord River monthly flows pre-regulation downstream of Dunham River

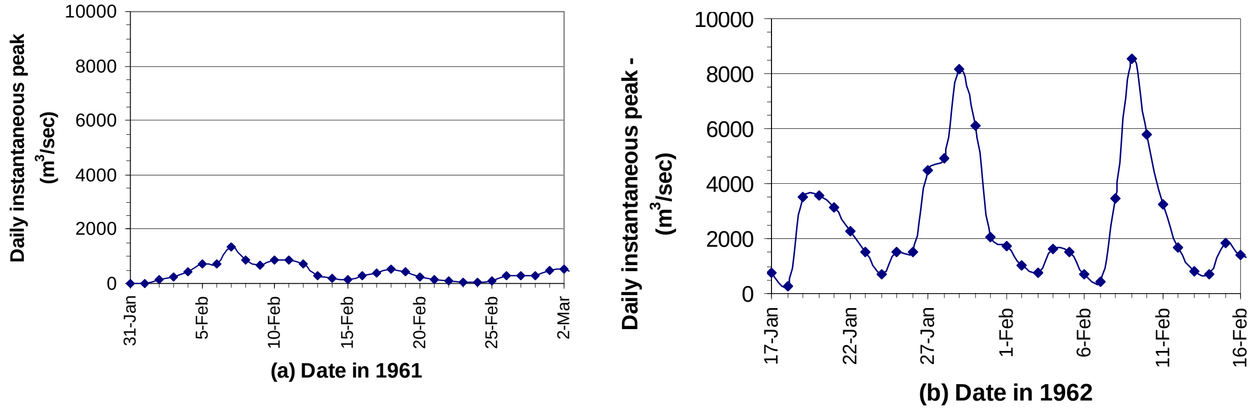


Figure 5 Peak flows pre-regulation –(a) dry wet, (b) average wet Ord River Dam site

2.3.3 Channel dynamics and sedimentation

The rapid flood response of the creeks and rivers of the upper Ord catchment are sufficiently powerful to mobilise and transport large quantities of eroded material into and down the Ord River watercourse. Sediment loads are especially high from areas where soils and landforms are prone to erosion and where grazing of cattle has exacerbated the erosion risk (Wasson et al., 1994).

Prior to regulation, sediment loads from the upper catchment were transported to the lower Ord River and, depending on the magnitude of the event, deposited on the floodplain, channel bed and levee areas or transported through to Cambridge Gulf. The current major levees of the lower Ord watercourse reflect the pre-regulation flood regime, with bank-full conditions occurring at flow rates of about 4,000–5,000 m^3/sec. Prior to regulation, floods of this magnitude occurred approximately once every two years (see Figure 8 and Figure 9). Larger floods would have overtopped the banks and deposited sediments across the floodplain every two to three years. Major inundation and sediment deposition could have been expected every five to ten years. Rodgers and Ruprecht (2000) provide estimates of the inundated areas for the 1 in 10 and 1 in 100 year average recurrence interval (ARI) pre-regulation flood events.

In smaller floods, contained within the main watercourse, sediments would have been deposited in pools and other parts of the watercourse where water velocities were below average (e.g. inside meander beds), only to be remobilised in subsequent, larger flood events. The peak flow rates during the dry wet-season year of 1961 were insufficient to exceed bank-full conditions (4000-5000 m^3/sec), while this occurred twice in eleven days in 1962 (see Figure 5).

Flood velocities have been sufficient to transport most fine sediments through to Cambridge Gulf, leaving a very mobile sand-gravel channel and river bed along much of the lower Ord River. This is considered a direct consequence of the dynamic and powerful nature of the river’s unregulated flood response.

2.3.4 Vegetation

Apart from stream flow monitoring, very little physical or biological data related to the Ord River was recorded before regulation. However, information relating to vegetation has been interpreted from aerial and other historical photography, remaining stands of older riparian vegetation and comparisons with the unregulated sections of the river or with other large floodplain rivers.

The hydrology and the channel dynamics strongly influenced the aquatic and riparian vegetation and the associated ecological communities. River Red Gums (*Eucalyptus camaldulensis*) and Coolabahs (*Eucalyptus microtheca*) occurred high on the banks often in fairly sparse and narrow stands. These species appear to have their seed fall near the end of the wet season with germination encouraged by the exposure of moist bare sediment as the river recedes. Seedlings could be destroyed by high energy floods in the wet season, with the result that mature stands only occurred at high elevations, in protected river bends or far from the river where there was less frequent flooding (Pettit, 2000).

Thickets of paperbark (*Melaleuca leucadendra*) saplings often established on exposed sediments fringing the pools or bars but were highly dynamic, being swept away when scouring flows subsequently occurred. Emergent and submerged macrophyte communities were also highly dynamic but were most stable in sheltered backwaters, pools and side channels.

Pettit (2000) has described the riparian vegetation and its reproductive phenology for the Ord River catchment above Lake Argyle, which still experiences a natural flow regime. The main anthropogenic impact on the riparian vegetation for this part of the catchment is grazing, which has also caused severe degradation of the riparian vegetation of the lower Ord River.

2.3.5 Fauna

The pre-regulation ecology of the Ord River fauna has been interpreted from limited information from other rivers in the Kimberley region (e.g. invertebrate surveys as part of the AusRivAS program; limited fish survey information from the Ord and Keep Rivers) and from empirical relationships developed for large floodplain rivers (Welcomme, 1985).

Like the vegetation, the fauna habitat was shaped largely by the big flushing flows and was consequently highly diverse and adapted to a boom and bust cycle driven by the hydrology. The coarse substrate within the main channel would have provided habitat for invertebrates in the interstitial spaces, while pebbles, cobbles and rocks provided shelter for larger invertebrates and small fish. Snags, undercuts, backwaters and pools formed within the complex channel morphology would have provided particular habitat types for what is likely to have been highly diverse communities.

The majority of fish breeding occurred in the wet season, being stimulated by the onset of flooding to move either onto the floodplain or downstream to the estuary. Movement would allow fish species to avoid the high energy, turbulent main channel and, for floodplain species, to take advantage of the warm, shallow productive waters on the floodplain. For species such as Barramundi (*Lates calcarifier*) that migrate to estuarine waters to breed, this may have been the only time that rock bars and other barriers were passable but may also have coincided with the availability of food and suitable nursery areas in coastal or marine areas. River channel breeders may have also been stimulated by the flushing out of stagnant water from the channel pools.

The end of the wet season would have provided the stimulation for species to return upstream, avoiding being stranded in inhospitable habitat as the floodplain dried or ensuring that there was sufficient flow in the channel to reach the larger upstream pools.

During the dry season, the flow decreased in most years to leave deep pools within the channel with little or no flow between them. By the end of the dry season, each pool may have contained a different fish community structure, depending on the dominance hierarchy of the species within the pool when it became isolated. As flows increased again in the next wet, the system was reset and species were re-distributed.

There is little reliable information on the waterbird use of either the river or its floodplain before regulation, but it is expected that numbers seen today may be similar. It is likely however that there may have been more extensive breeding habitats available in the lower sections of the floodplain due to more regular over-bank flow in this section of the river before the dams were constructed.

Both estuarine saltwater (*Crocodylus porosus*) and freshwater (*Crocodylus johnstoni*) crocodiles are found in the Ord River and along most of the Kimberley river systems. There is very little information on their numbers prior to regulation although it would be expected that their numbers and distribution were strongly dependent on availability of suitable habitat, particularly for breeding, and food sources.

2.3.6 Water quality

During the wet season, there would have been significant sediment and nutrient inputs from the surrounding and upstream catchments. However, the high flows are likely to have flushed these quickly through to the estuarine reaches. The high turbidity, high flow rates and consequent dilution capacity would have made algal blooms and de-oxygenation events unlikely[12].

Under unregulated conditions, it is likely that water quality would have deteriorated towards the end of the dry season, particularly as pools became shallower, water temperatures increased and oxygen was depleted. It is likely that biological productivity was probably lower under the pre-regulation conditions as nutrient concentrations were probably lower. The larger pre-regulation flood regime would have deposited particulate bound nutrients onto the floodplain and transported those bound to finer particles through to Cambridge Gulf more efficiently than the current regime.

The salinity of river water would have been affected by estuarine water up to at least Carlton Crossing at times of spring tide. This would have occurred frequently during the dry season and in the early months of the wet season when stream flow was low. Under flood conditions, however, the saline interface moved well downstream. The major floods which occurred in the region are of similar magnitude to the incoming spring tide. This may have pushed the saline interface to the estuarine mouth at Cambridge Gulf (Wolanski *et al*., 2001).

[12] However, evidence of reductions in dissolved oxygen levels has been observed in the estuarine reach of the lower Ord River (downstream of The Rocks). These have occurred at times of major floods (D. Palmer, pers. comm.), and are presumed to be related to high BOD or COD levels of the inflowing flood waters.

2.4 The lower Ord River since regulation

2.4.1 Hydrology

The changes to the hydrology of the Ord River began with the construction of the Kununurra Diversion Dam in 1963 but the most significant changes occurred after the construction of the Ord River Dam in 1971-72. In 1995, the base of the Ord River Dam spillway was raised by 6 m to provide additional head for power generation. The dam can now store 10,700 GL in Lake Argyle at full supply level, or over 2.5 times the average inflow. The maximum flood storage however, exceeds 30,000 GL and represents about 1.5 times the maximum estimated annual inflow volume since rainfall records commenced (from 1906). The changes to the flow regime have been substantial. The following sub-sections describe the changes in annual and seasonal volumes, patterns of monthly flows and changes in the frequency of annual peak instantaneous flow rates. Estimates of the changes in flow resulting from the water diverted for irrigation, compared with the effects of the reservoir and dam operational practice, are also made.

Annual and seasonal changes in flow volumes

River regulation and irrigation diversions have reduced annual flows in the lower Ord River. Table 3 presents estimates of the average and median annual flow in the lower Ord River just downstream of the Dunham River under unregulated and regulated conditions for the same hydrologic period of 1974-75 to 2004-05. The annual average flow is estimated to decline by 35 per cent. The reduction is a combination of the high net evaporation loss from Lake Argyle and the water diverted from Lake Kununurra for irrigation use. More than 85 per cent of the reduction is due to net evaporation loss from Lake Argyle.

Construction of the Ord River Dam has also caused large change in the seasonal pattern of flow in the lower Ord River (Table 3). Over the 31 years since 1974-75, average wet season flows reduced by 67 per cent respectively and average dry season flows increased by 439 per cent. Similar changes are apparent in median wet and dry season flows in the lower Ord River.

The lower Ord has become a perennial system since regulation. In ecological terms, the dry season changes have effectively transformed the lower Ord River into a wet tropics river from a dry tropics river. Under typical dry season conditions, as reflected by the pre- and post-regulation median, dry season flows have increased by over 1,000 GL.

Table 3 Annual and seasonal flows in the Ord River downstream of Dunham River

Statistic	Mean stream flow			Median stream flow		
Lower Ord River flows (1974-75 to 2004-05)	**Pre-regulation (GL)**	**Post–regulation (GL)**	**Change (%)**	**Pre-regulation (GL)**	**Post–regulation (GL)**	**Change (%)**
Water Year (Nov - Oct)	6,070	3,940	-35	4,740	2,830	-40
Wet Season (Nov-Mar)	5,690	1,890	-67	4,700	1,380	-73
Dry Season (Apr - Oct)	380	2,050	439	230	1,240	365

The effects of regulation on monthly flows in the lower Ord River are shown in Figure 6. The figure compares estimates of the percentiles of monthly flows in the lower Ord River below the Dunham River confluence, under unregulated and post-regulation conditions. Also included are percentiles of monthly flows estimated to have occurred if the spillway had not been raised and the ORDHP Station not established in 1995-96. In each case the estimates are based on the same hydrologic period (1974-5 to 2004-5).

Decreases in the 50th to 90th percentile flows between December and March after regulation reflect the storage of wet season stream flow in Lake Argyle (Figure 6(b) and (c) compared with Figure 6(a)). Increases in the 50th to 90th percentiles between April and June reflect the spillage of water from Lake Argyle following wet seasons with above average stream flow. Increases in 10th and 25th percentiles between April and November reflect the releases made through the outlet works of the Ord River Dam that exceed the irrigation diversions made from Lake Kununurra.

Differences between Figure 6(b) and 6(c) are much smaller than the differences from Figure 6(a). This indicates that the changes in lower Ord River flows due to raising of the base of the spillway and releasing water to generate hydro-electricity are secondary to the changes due to the initial regulation[13]. Nevertheless, flows between June and October have been between 5 to 10 m^3/sec higher since 1995-96, and reflect the additional releases being made to generate hydro-electricity.

The seasonal changes reflect the nature of the spillway configuration (see peak flow changes below) and operational practice since the Ord River Dam was constructed. In the early years of operation, when irrigation diversion rates were commonly less

[13] Note that differences between Figures 6(b) and (c) do not fully reflect the changes to lower Ord River flows following the operation of the power station, as Figure 6 (c) includes data from the period before the power station was constructed (1995-96).

than 5 m^3/sec, releases of 40 to 50 m^3/sec were maintained for ease of operation of the Kununurra Diversion Dam and the M1 Channel Supply Area (M1 Supply Area). As dry season water based tourism developed on Lake Kununurra through the 1980s, additional releases to enable tour boat operators to navigate through Carlton Gorge to the base of the Ord River Dam became normal practice. Releases of 50-60 m^3/sec were common. With the construction of the ORDHP Station in 1995-96 releases have averaged 60 m^3/sec and exceeded 70 m^3/sec at times of high power demand and low lake level. Regulation by the Ord River Dam has also reduced the variability of monthly flows in the lower Ord River as shown in Table 4.

Table 4 Monthly flow variability ‡- Ord River downstream of Dunham River

Regulation cases[1]	**Nov** %	**Dec** %	**Jan** %	**Feb** %	**Mar** %	**Apr** %	**May** %	**Jun** %	**Jul** %	**Aug** %	**Sep** %	**Oct** %
No regulation	132	90	79	85	152	174	212	344	363	496	340	317
Post-dam Pre-ORDHP Station	30	42	55	91	128	129	129	124	115	87	55	54
Post-dam and ORDHP Station	34	39	50	85	122	134	131	124	105	68	44	41

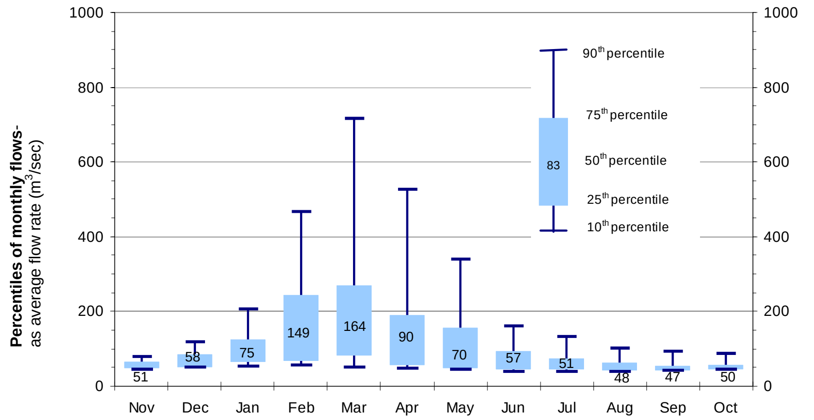
‡ Monthly flow variability – standard deviation/ mean expressed as a percentage

[1] Cases are same as described in Figure 6

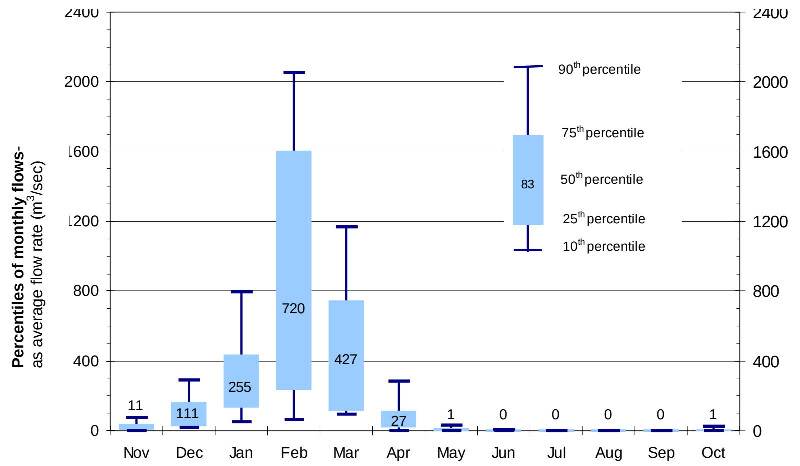
Peak or flood flow changes

As described in Section 2.3.1 and shown in Figure 1, prior to regulation the Ord River responded rapidly to heavy rainfall and caused regular flooding of Ord River floodplain. The Ord River Dam was designed to provide a large flood storage in Lake Argyle, to minimise the flood risk to the town of Kununurra and new irrigation areas, and to save costs of constructing a conventional spillway. A relatively small capacity spillway, cut into a saddle approximately 7 km from the Ord River Dam, was constructed to discharge floodwaters from Lake Argyle and return spillage flows to the Ord River about 30 km upstream of the Kununurra Diversion Dam (see Figure 3 and Figure 7).

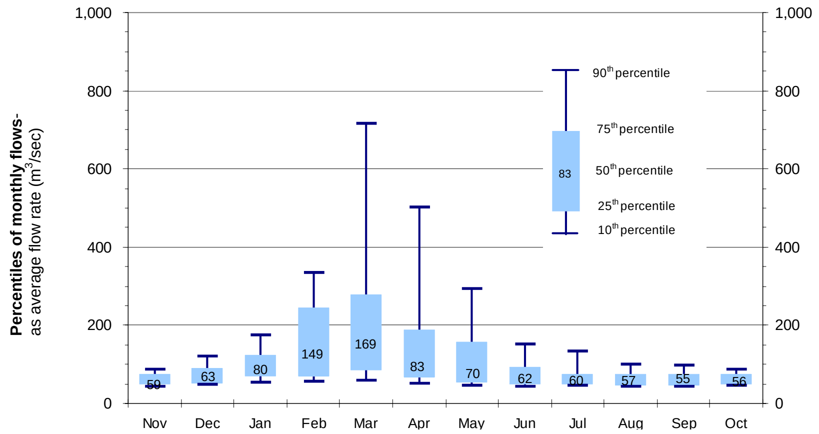
Hence large inflows are captured in Lake Argyle's flood storage (above the base of the spillway) and the flood storage discharged slowly over several months. The spillway outflow rate can be more than 10 times lower than inflow rate to the Ord River Dam. Major floods are now much less frequent on the lower Ord River. The high flows that do occur are generated from heavy rains that fall in the Dunham River catchment or the Ord River catchment between the Ord River and Kununurra Diversion Dams.



(a) Unregulated flows downstream of the Dunham River – no Ord River Dam



(b) Post-dam, pre-hydro conditions –no hydro-power station at the Ord River Dam



(c) Historic post-regulation conditions- Ord River Dam with hydro-power station from 1996

Figure 6 Monthly flow percentiles in the lower Ord River flows under (a) unregulated, (b) post-dam, pre-hydro, and (c) historic post-regulation conditions (1974-75 to 2004-05).

Figure 7 Ord River Dam Spillway, Ord River Dam Embankment and Lake Argyle

Figure 8 compares flood frequency distributions of the Ord River just below the Dunham River confluence under pre- and post-regulation conditions (Rodgers and Ruprecht, 2000). Prior to regulation, the annual peak flow with a 50 per cent probability of being exceeded in any one year (e.g. the flood with a 50 per cent Annual Exceedance Probability (AEP)[14], was approximately 4,800 m^3/sec. Under the current level of development, the flood with the same AEP was estimated at about 1000 m^3/sec. Greater reductions occur with larger, less frequent floods. The 1 per cent AEP flood (or 1 in 100 year ARI flood) is estimated to have reduced from over 52,000 m^3/sec to approximately 10,000 m^3/sec under the current level of development (Figure 8).

[14] Also termed the 1: 2 year Annual Recurrence Interval flood or 1:2 ARI flood.

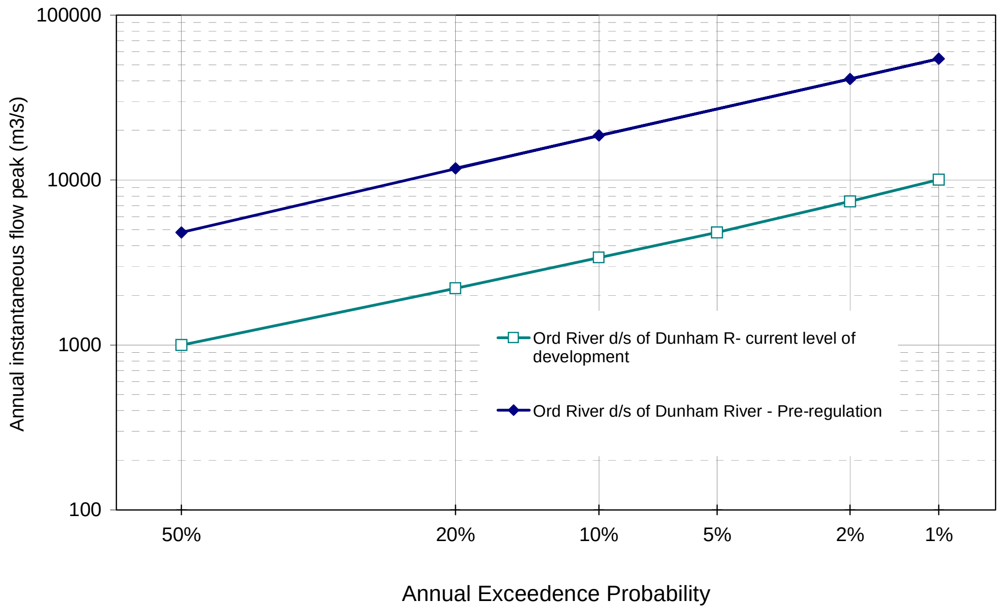


Figure 8: Pre- and post-regulation annual flood frequency distributions of the Ord River downstream of the Dunham River confluence

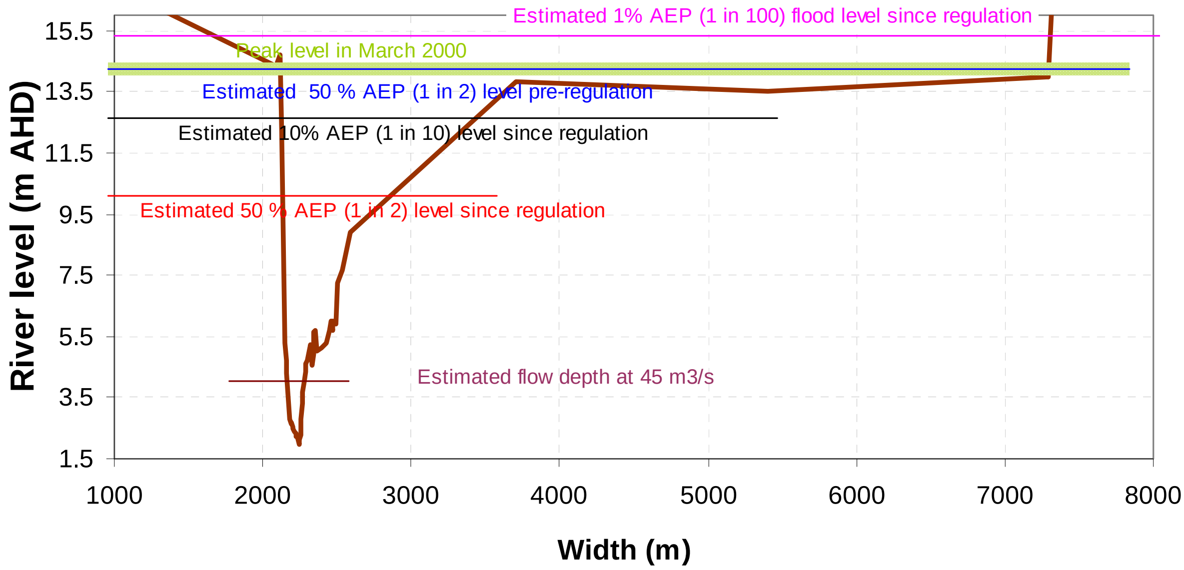


Figure 9 Estimated flood levels just upstream of Carlton Crossing (cross-section 62827) pre- and post-regulation

The reduction in high flows following regulation has caused a corresponding reduction in the extent and frequency of inundation of the Ord River floodplain. Rodgers and Ruprecht (2000) have mapped the change in inundation areas for the 10 per cent and 1 per cent AEP floods. Figure 9 presents river levels at one cross-section that show the probability of over-bank flow has declined from approximately 50 per cent prior to regulation to less than 10 per cent after regulation.

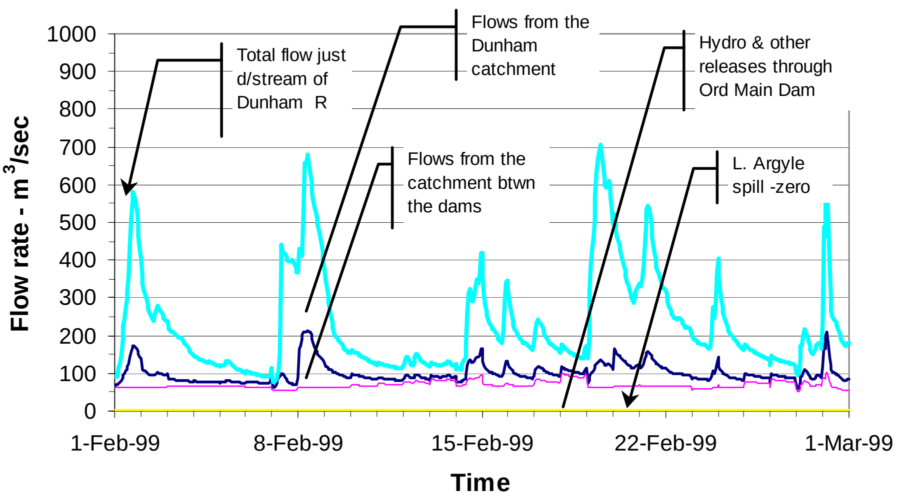


Figure 10 Contributions to lower Ord River flows during February 1999

The lower Ord River peak flows are now dominated by the unregulated flows of the Dunham River and from the catchment downstream of the Ord River Dam (see Figure 10). Spillage from Lake Argyle contributes in years when rainfalls are above average, and can be a major component in very wet years.

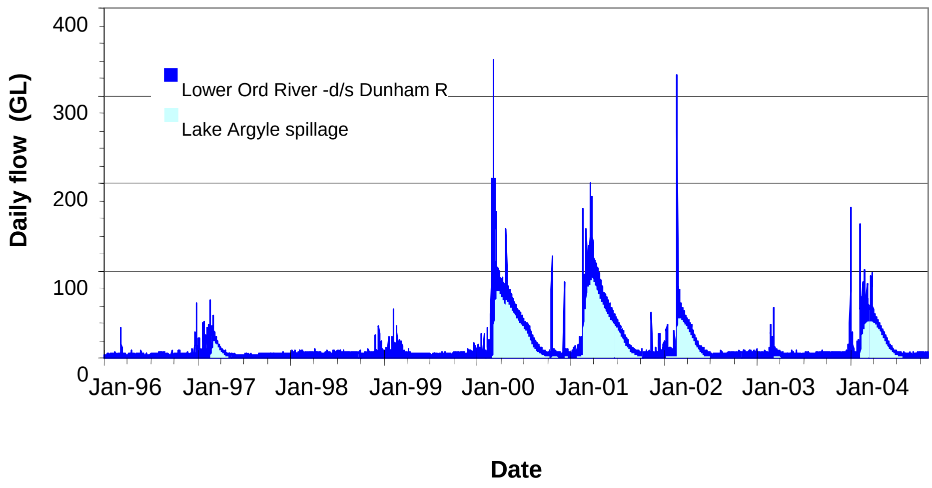


Figure 11 Estimated daily flows of the lower Ord from 1996 –downstream of Dunham River

2.4.2 Sedimentation and channel dynamics

The loss of the high magnitude floods means that there is greatly diminished stream power and so limited mobilisation of the coarser sediments (gravels, sands) and a substantially reduced likelihood of future floods altering the channel planform. From

Figure 8, events which just exceed the bank-full conditions approximately 4,000+ m^3/sec now only occur with a probability of exceedence of 7 per cent (roughly a 1 in 14 year ARI flood) compared with slightly less than 50 per cent (1 in 2 year ARI flood) prior to regulation (see Section 2.2.2). More significantly, larger peaks of say 10,000 m^3/sec, when significant scouring and channel reshaping could be expected, had a 20 per cent probability of exceedence (1 in 5 year ARI) prior to regulation, but now have a probability of exceedence of less than 1 per cent (or have an ARI of less than 1 in 100 years).

The large sediment load from the catchment of the Ord River Dam (24 mt/yr) is no longer delivered downstream, with over 99.9 per cent being trapped in Lake Argyle. Sediment load in the lower Ord River is now dominated by contributions from the Dunham and the catchment between the dams where erosion of the Carr Boyd Ranges is the likely dominant source. Rodgers and Ruprecht (1999) estimate the average annual post-regulation sediment loads of the lower Ord River to be about 0.6 mt/yr or only 2.4 per cent of the pre-regulation loads. Sediment load of the lower Ord River also comes from irrigation drainage returns, local gully development on the floodplain and channel bank sources. While locally significant, their contribution would be small relative to the pre-regulation loads.

The Environmental Geomorphology Research Group at the University of WA has been undertaking channel surveys of the lower Ord River. Recent post-regulation channel surveys between the Dunham/ Ord confluence and Valentine Falls have shown extensive deposition of sediments in various parts of the channel, and especially an accretion of point bars. Fine sediment deposition is occurring on the margins of point and lateral bars, channel margins and in mid-channel regions, and these forms appear to be closely linked to aquatic vegetation. The aquatic vegetation traps sediments and stabilises the depositional forms, which are in turn colonised by more substantial vegetation stands. The result is a gradual decrease in channel capacity, with ongoing channel encroachment by first aquatic, and then riparian vegetation.

Evaluation of the channel since high flow events in March 2000 suggests major dispersion of channel sediments within the system but that this has not caused the total removal of stored material (Cluett, 2001). The impact was not uniform along the river with some reaches undergoing major reworking and others showing minimal visible change.

2.4.3 Vegetation

The channel deposition processes and stable flows have encouraged the development of wide beds of emergent and submerged macrophytes in most shallow areas. Species include Marshwort (*Nymphoides indica),* the native Bulrush *(Typha domingensis),* Tropical Weed *(Phragmites karka),* Potato Vine *(Ipomoea aquatica)* and Preslia *(Persicaria attenuata).* In *Typha* beds, species such as

Pandanus aquaticus, White Dragon Tree (*Sesbania formosa)* and *Melaleuca leucadendra* often become established in the trapped sediments.

The constant flows and the reduction in high flow scouring events post-regulation have reduced the frequency of germination events for the high bank vegetation, but encouraged the development of a more stable, dense band of riparian vegetation approximately 15 m wide along the water's edge within the main river channel. In places, this is also occurring on mid-channel bars to form islands. Thickets of *M. leucadendra* saplings may form tall woodlands or forest on such sites. Similarly, species such as *P. aquaticus,* Leichardt Pine *(Nauclea orientalis), Ficus* species and *Cathormion umbellatum* which once occurred in isolated sheltered sites, have expanded to form extensive fringing woodlands as a result of the constant water levels.

The stability of the post-regulation riparian vegetation is largely due to the diminished frequency of high flow events, although the flows experienced in early 2000 were of sufficient velocity to remove some areas of vegetation. Cluett (2001) indicates the vital role that the additional post-regulation riparian and aquatic vegetation played in stabilising sediment stored in the channel during the March 2000 flood. While fringing vegetation sustained considerable damage and much floating and submerged vegetation was removed from channel margins, significant plant communities on the channel edge have survived the force of the flood. This vegetation showed signs of healthy recovery, particularly the *Pandanus*, *Phragmite*s and *Typha* species.

Since the March 2000 flood, further high flows have occurred in three of the subsequent four wet seasons (see Figure 11) and caused additional changes to the lower Ord's vegetation communities. The five wet seasons from 1999-2000 has been a period of unusually high stream flow in the lower Ord River. The period contains three of the five highest peak flows estimated to have occurred in the 31 years since Lake Argyle first filled. The emergent and submerged macrophytes, in particular, have been affected by this sequence of wet-season flows. The highest peak flows largely removed the macrophyte communities from the main channel, although they began to re-colonise during the following dry season. The magnitude and sequence of high flows in the subsequent wet seasons influenced whether re-colonisation continued or further scouring occurred.

Observations made over the last five years have emphasised the dynamic nature of the riverine ecosystem of the lower Ord and the role that hydrologic variability plays in generating change in the ecosystem.

2.4.4 Fauna

Surprisingly, alteration to the hydrology of the system appears to have had little impact on the composition of fish populations in the lower Ord (Trayler *et al.,* 2006). This is based on the results of comparative studies that sampled fish in the lower

Ord and nearby unregulated systems including the Keep, Dunham and Pentecost which demonstrated that there was no significant difference in species richness, abundance or biomass between regulated and unregulated systems. It therefore follows that significant differences between pre- and post-regulation fish assemblages in the lower Ord are unlikely. A locally significant recreational Barramundi (*Lates calcarifier*) fishery is now based on the new flow regime.

While rainfall generates some local ponding and drainage to the river via Wild Goose and Reedy Creeks each wet season, inundation of the lower floodplain from the Ord River has greatly reduced in frequency, extent and duration (see Section 2.4.1 above). The main river bed now principally consists of the sand and gravel bars on the inside of meander bends and some low-lying parts of the banks. It is possible that some of the finer sediments previously transported to Cambridge Gulf are now causing in-filling of benthic interstices within the sand and gravel. The deeper pools which once provided dry season refugia could become shallower and filled with fine sediment. There is evidence of this process contributing to the formation of sediment islands and accretion of river banks as material is stabilised by subsequent riparian vegetation growth. Evidence of accumulation of fines in the deeper pools is not as clear (Cluett, 2000) and pools with significant depth still occupy about 80 per cent of the lower Ord River. Some accumulation of fine material in deeper pools is likely to occur over extended periods between high flow events. If the remaining high flow events do not remobilise this material, shallower pools will develop in the longer term. If this occurs, a reduction in species diversity, carrying capacity and population size may occur as preliminary results of habitat survey work indicate that both fish species (and size classes) and invertebrate taxa show distinct preferences for specific habitats (Storey, 2002a, 2002b).

Vegetation established on the river banks since the construction of the Ord River Dam is important to the post-dam fish community. Preliminary results of studies undertaken on fish ecology suggest that larger individuals of the Barramundi species (*Lates calcarifier*), as well as some other species, show a preference for the habitat created by the flooded riparian vegetation (Storey, 2002a). The river channel itself may function more like a floodplain due to the steady water levels, low turbidity, low flushing and finer benthic sediments. Preliminary results suggest that submerged vegetation provides an important habitat for smaller fish with some species only occurring in this habitat and backwater areas (Storey, 2002a). In addition these areas provide substrate and habitat for the food source of non-predatory fish (epiphytic growth of algae, diatoms and invertebrates) as well as carbon inputs to the system.

Continuing channel encroachment through sedimentation processes and stabilisation by vegetation may have a long term impact on the area of available in-stream habitat due to the reduction or loss of deeper pools, bank undercuts, backwaters and available snags. This is likely to be of most concern for the larger fish species and may result in smaller populations of these in the longer term.

Miriuwung Gajerrong people suggest that the upstream extent of estuarine crocodiles has increased since the Ord River Dam was built. The dams themselves constitute major barriers to the migration of fish species. Thus the Ord River upstream of the Kununurra Diversion Dam is now inaccessible to those species that are estuarine breeders, including Barramundi (*Lates calcarifier*).

Waterbirds do not use the channel extensively during the wet season when flows are strong. However, in the dry season flocks of Magpie Geese *(Anseranas semipalalmata)*, Egrets and other waders do use the channel, feeding in shallow water at the margins or sometimes roosting on the river and feeding in the irrigation area.

2.4.5 Water quality

A secondary impact on the ecology of the lower Ord system since regulation has been through changes to water quality. Reduced flows, increased deposition of fine sediments, increased biological activity (in the form of submerged and emergent macrophytes and associated epiphytic growth) and increased input of nutrients, has apparently increased the nutrient cycling capacity in the system.

There have been occasional fish kills associated with pesticide toxicity in both the Ord and the Dunham Rivers downstream of the irrigation drainage return flows, and occasional algal blooms in drains and the lower Dunham River. There is now a regular monitoring program for nutrients and pesticides.

2.5 Ramsar wetlands and Cambridge Gulf

Lakes Argyle and Kununurra (as well as their associated wetlands) and the lower Ord River floodplain were listed as Wetlands of International Importance under the Ramsar Convention in 1990 (Watkins *et al*., 1997). Their location in relation to the Ord River is shown in Figure 12. Table 5 indicates the features of their ecosystems used to support their nomination against the criteria of the convention.

2.5.1 The Ord River floodplain

The Ord River floodplain site includes two main areas of wetland values: the permanent and seasonal wetlands of the Parry Lagoons Nature Reserve; and the estuarine and marine habitats of the Ord River Nature Reserve and the False Mouths of the Ord River (Watkins *et al*., 1997).

Parry Lagoons and the associated floodplain area are important in terms of breeding, species richness and abundance of waterbirds. There have been 77 waterbird or water-associated species recorded at the floodplain area, with up to 27,000 individual birds. Magpie Geese *(Anseranas semipalalmata)*, Egrets, Ibis and Herons are among the species that breed there in the wet. The value of the area for waterbirds is increased by the extent of flooding but is also inversely related to the amount of water elsewhere in the north-west of WA and in the NT. Before the dams were constructed, it is likely that the most extensive flooding of the area came from over-bank flow from the Ord River. With the frequency of flooding reduced by the construction of the Ord River Dam (Figure 8), the main source is now local rainfall and Parry Creek's local catchment (approximately 450 km^2). This was evident during the high rainfalls and flood events of March 2000.

The tidal influenced areas of the lower Ord and the False Mouths of the Ord River support some of the most extensive mangrove communities in the region. Fourteen species of mangrove have been recorded from the area. Mangrove communities throughout the site exhibit strong patterns of species zonation reflecting species preferences for particular tidal flooding regimes.

Table 5 Nomination details for Ramsar-listed wetlands (from Watkins et al., 1997)

Criteria	**Ord Floodplain**	**Lakes Argyle and Kununurra**
Criteria based on representative or unique wetlands: • good example of specific type of wetland characteristic of its region	• Yes	• not applicable (man-made wetlands)
Criteria based on plants and animals: • assemblages of rare, vulnerable or endangered species in appreciable numbers • special value for maintaining the genetic and ecological diversity of a region • habitat at critical stage of biological cycle	Estuarine crocodile: • located close to major breeding area • impressive specimens in area. Zitting Cisticola: • rare and threatened bird species. Mangrove habitat: • 14 species of mangrove	Freshwater crocodile: • Lake Argyle supports population estimated 10,000-20,000; Lake Kununurra estimates 3,000-5,000

Table 5 Continued

Criteria	**Ord Floodplain**	**Lakes Argyle and Kununurra**
Specific criteria on waterfowl: • regularly supports 20,000+ waterfowl • substantial number indicative of wetland values, productivity or diversity • more than 1 % of a specific waterfowl population	Parry Ck Floodplain: • 77 species including 22 listed under international conservation treaties • estimated >20,000 birds use the area annually Parry Lagoons • may be one of five most important wetlands in WA for migratory shorebirds (in terms of species) and ranked tenth most important in Australia. Highest breeding concentration of Magpie Goose (*Anseranas semipalalmata*) in WA Mangrove areas: • includes almost all specialist mangrove species in WA. Part of the only population of Black Butcherbird in the State	Lake Argyle: • 74 spp recorded (22 listed under international conservation treaties >100,000 birds use Lake Argyle annually Lake Kununurra: • 160 species Significant breeding populations of Little Grassbird, Little Bittern, Spotless Crake and non-breeding migrant population of Oriental Reed Warbler
Description	Mangroves and salt flats, seasonally flooding plains and permanent freshwater lagoons. Three distinct wetland units: Parry Lagoon Nature Reserve: • dominated by seasonally flowing Parry Ck running through alluvial complex. Persistent freshwater billabong and swamps Ord River Nature Reserve: • extends from the Parry Lagoon reserve to the Cambridge Gulf. Saline floodplain soils False Mouths of Ord: • delta of tidally inundated coast mud flats and islands	• deep lakes and fringing inundated grassland and emergent macrophytes and trees
Area	130,000 ha	150,000 ha

2.5.2 Lakes Argyle and Kununurra

The nomination details for Lakes Argyle and Kununurra also recognise that they are man-made wetlands and that their primary management purpose is for water supply. However, they also provide important dry season refugia for very large numbers of waterbirds on occasions (Lane *et al*., 1996). Most birds use the southern end of Lake Argyle where there are extensive areas of shallow water and macrophyte beds where birds can feed.

Within Lake Argyle itself, water levels fluctuate by about 3 m each year under the influence of average inflows, evaporation and releases for irrigation and hydro-electric power generation. However, with large inflows during the wet season the level may change rapidly and by as much as 10 m in one month.

Between the two dams, the water level in Lake Kununurra and the Carlton Gorge river reach is relatively constant and is maintained by the operation of the Kununurra Diversion Dam gates. Lake Kununurra supports nesting of Comb-crested Jacana (*Irediparra gallinacea*), being favoured by the lake's stable water levels. These conditions also encourage greater encroachment of *Typha*, probably to the detriment of longer term waterbird values. As water levels will remain unchanged, waterbird values are not at risk from additional irrigation allocations and are probably more at risk from pressure to sub-divide small holdings around Lake Kununurra as the town of Kununurra grows.

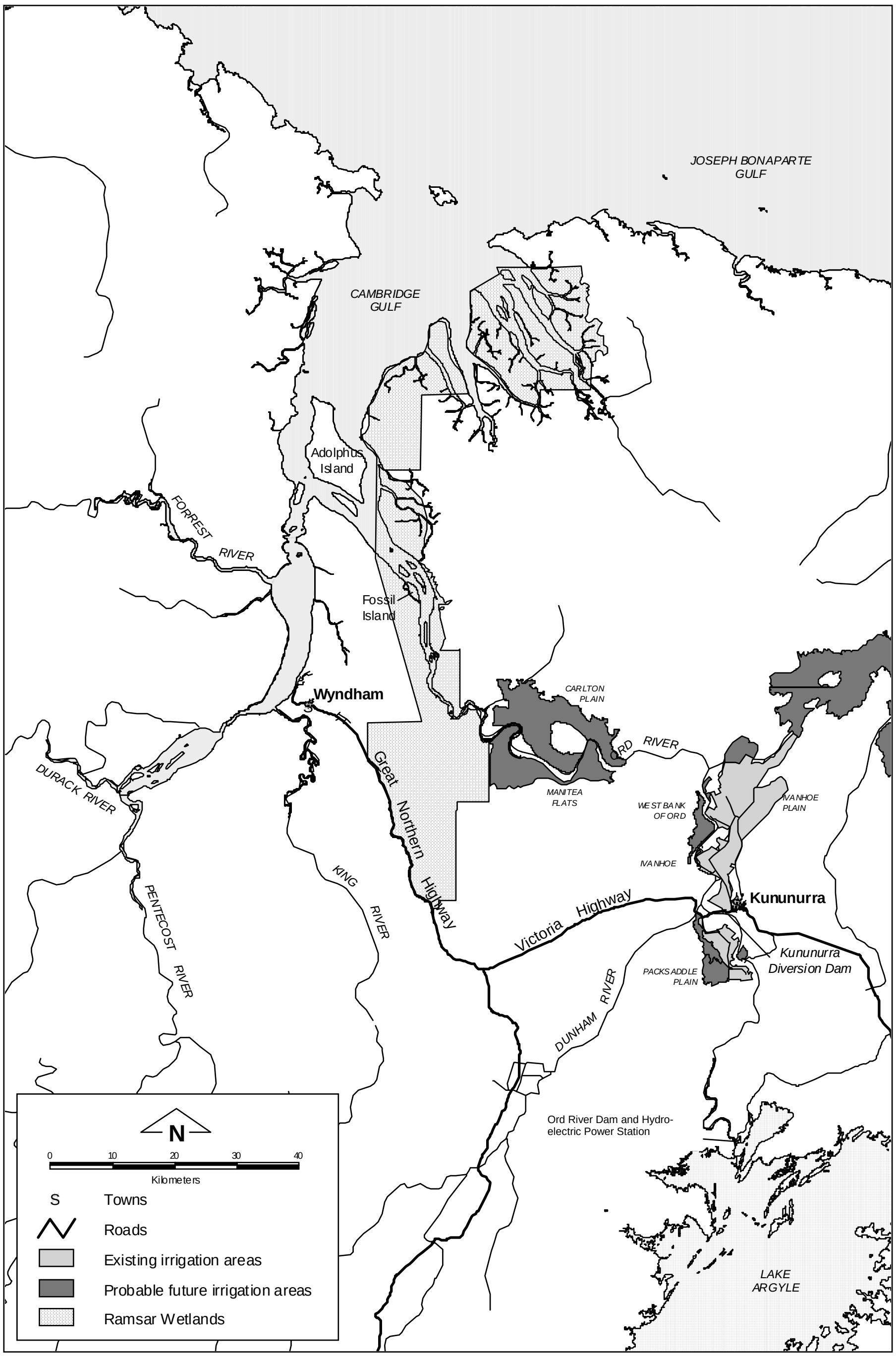


Figure 12: The lower Ord River in relation to Ramsar Wetlands and Cambridge Gulf

2.5.3 Cambridge Gulf – the receiving water body

From The Rocks (Figure 2) the Ord River becomes a 65 km long estuary before it discharges into Cambridge Gulf near Adolphus Island (Figure 12). Cambridge Gulf itself is an estuarine water body of approximately 1,000 km^2, which connects to the marine waters of Joseph Bonaparte Gulf and the Timor Sea. The Ord River is the largest of five major rivers that drain into Cambridge Gulf (Figure 12 and Table 17).

Commercial and recreational fishing interests use the port of Wyndham in Cambridge Gulf to fish the coastal waters between the Keep River in the east and the Mitchell River in the west. Cambridge Gulf itself is one of the most important of these areas. The commercial Barramundi Gill Net Fishery has three operators that use Cambridge Gulf and the areas to the west. Fishing of prawn species also occurs in northern coastal waters although most commercial activity occurs further to the east in coastal waters off the NT.

The physical and biological processes of the Ord River estuary and Cambridge Gulf are dominated by the macro-tides of the area. Spring tides are commonly 7 m in Cambridge Gulf and at the mouth of the Ord River estuary and generate strong currents each tidal cycle. Highly turbid, well-mixed waters result as the currents re-suspend fine sediments and redistribute them throughout the gulf (Wright *et al*., 1973). At the upper end of the estuary (near The Rocks) the amplitude of the spring tides reduces to about 2 m. However, sufficient tidal currents are still generated to induce vertical mixing of the estuarine and incoming river water (Wolanski *et al*., 2001). Salinities are generally less than seawater, particularly towards the end of the wet season when the maximum dilution of marine waters by river water occurs. Salinities of the flood (incoming) tides in the Ord River estuary reflect the mixed salinities of Cambridge Gulf and commonly range between 25 ppt[15] and 30 ppt. During the wet season ebb tide salinities can reduce to below 10 ppt and have been recorded as low as 2 ppt following large flow events.

Preliminary research studies have found differences in the banana prawn catch between the Durack and Ord River arms of Cambridge Gulf and proposed that the differences reflect the effects of regulation on the Ord River. Unlike Western King Prawns (*Penaeus latisulcatus*), Banana Prawns (*Penaeus merguiensis*) are migratory and spend part of their life cycle as larvae in upstream fresh water bodies. In the early wet season, local rainfall and drainage fills ponds on the lower Ord River floodplain. These ponds become connected to the river after heavy rains via either local creek drainage or sheet flow over the main river bank. The connection, although often brief, provides a mechanism for aquatic organisms, with ability to move against the flow, to enter the floodplain. In tidal areas this occurs readily when the heavy rains coincide with high tides (Scott Goodson, pers. comm.). The Banana Prawn (*P. merguiensis*) larvae commence development on the floodplain, are then flushed down-river by subsequent floods and grow to maturity in estuarine waters. Reductions in over-bank flooding since the construction of the Ord River Dam appear to have reduced their flushing back to the estuary and reduced the Banana Prawn (*P. merguiensis*) catch in the Gulf.

[15] ppt -parts per thousand

Preliminary research on key processes governing the hydrodynamics, salinity and sediment dynamics of two arms of Cambridge Gulf (east and west) were investigated by a research team from the Australian Institute of Marine Science (Wolanski *et al*., 2001). Results indicate that the west arm areas are in a relatively stable state, and that they are likely to have been stable since 1888[16]. The estuary of the west arm appears to be tidally self-scouring. This contrasts with the Ord River (east arm) where the tidal hydrodynamics, bathymetry and salinity regime of the Ord River estuary has changed greatly. Prior to European influence, the bathymetry of the Ord River estuary was probably controlled by a dynamic equilibrium between the macro-tides and river floods during the wet season. The macro-tides regularly pumped sediment from Cambridge Gulf upstream into the Ord estuary, and occasional major river floods scoured the channel and exported sediment seaward. To investigate this, the researchers modelled the estuarine scouring potential of the (pre-regulation) 1959 flood. The peak flow rate of 30,500 m^3/sec (at the dam site) was very similar to the peak tidal discharge at the river mouth at spring tides, indicating that the Ord River estuary would have been fresh up to its mouth. The sediment model predicted that the estuary may have scoured significantly during such floods, possibly by 0.5-1.0 m in the upper reaches and a lesser amount in the lower reaches. Thus, one such large river flood may have removed from the estuary the sediment accumulated over 20 years of tidal input.

The research team estimated a major accumulation of sediment (about 20 million m^3) in the estuarine sections of the Ord River over a 30 year period after the Ord River Dam was completed. Sedimentation has resulted in cross-sectional areas of the estuary decreasing by about 50 per cent over the period. A consequence has been an increase in the extent of mangroves in the Ord River estuary, particularly on the Fossil Islands. Wolanski *et al*. (2001) propose that the accumulation is a result of the absence of large floods post-regulation. As these large floods no longer occur, they cannot periodically scour the estuary of sediment accumulated from tidal input.

The accumulation process was numerically modelled over a 100 year simulation. The results suggested that the macro-tides would continue to pump sediment from Cambridge Gulf upstream into the Ord estuary although the rate of accumulation reduced through the simulation period as the estuary silted up. Most sedimentation initially occurs in the lower reaches of the estuary while upper estuary accumulation becomes a higher proportion in the later part of the sequence.

There can be little doubt that the estuarine sediment accumulation is related to the presence of the Ord River Dam. While numerical modelling has indicated tidal pumping is the main accumulation mechanism, caution should be used in drawing quantitative conclusions about accumulation rates or management implications from this preliminary work. For example, no river input and therefore no river scouring potential was modelled in the post-regulation scenario. While a major reduction in erosive power has occurred since regulation, the high flows over the last five years

[16] The Durack family commenced grazing cattle in the Ord Catchment in 1888.

indicate that flooding and scouring can still occur in the lower Ord River and estuary. A new dynamic balance in the estuarine system is expected to develop over time based on the new (reduced) flood regime and a smaller estuary.

As the accumulation process is driven by stronger flood tide currents relative to ebb tide currents, sediment build-up is limited to the estuarine sections of the river, principally downstream of The Rocks. Areas upstream of the local tributaries of Wild Goose and Reedy Creeks, near the limit of the tidal range, may accumulate sediment in the longer term. However, the creeks themselves have not yet been affected by siltation and continue to drain to the river each wet season. Their local scouring power, together with lower expected sedimentation rates, suggests that they will continue to do so.

3 Ecological Water Requirements

3.1 Definitions

The Water and River Commission's (the Commission) policy on Environmental Water Provisions (WRC, 2000b) guides the Commission's water allocation planning and decision-making in relation to allocating water to the environment.

The policy describes the role of Ecological Water Requirements (EWR) and Environmental Water Provisions (EWP) in setting the sustainable diversion limit of a water resource. EWR of a water resource are defined as water regimes that, when maintained, will protect the natural ecological processes and biodiversity of the resource's water-dependent ecosystems to a low level of risk. EWR are determined on the basis of the best available scientific information and are the primary consideration in the determination of EWP. EWP are water regimes made available to the environment as part of the Commission's water allocation decision-making, after considering ecological, social and economic needs for water.

This section summarises the development of interim EWR for the lower Ord River. Further details of the process are provided in Appendix 3. Section 4 describes the use of interim EWR together with consideration of social (including cultural) and economic values in the formulation of an interim EWP flow regime for the lower Ord River.

3.2 EPA advice and revised management objective

In its review of the 1999 draft plan and associated submissions (Appendix 2 and EPA, 1999), the Environmental Protection Authority advised the Commission that:

"…as the riverine environment downstream of the existing dams on the Ord River are already substantially modified, there may not be value in trying to maintain a downstream river flow which mimics pre-dam flows. In view of the significant ecological and social implications of altering the downstream environment once again, the EPA believes it would be more appropriate to base the interim EWP on protecting environmental values which are sustainable under post dam flows and so preserve the riverine ecosystem which has adapted to these changes."

Consequently, the Department has determined an interim EWR that reflects the water regime necessary to maintain the ecological processes and biodiversity of the post-regulation water-dependent ecosystems.

3.3 Development of an interim EWR

The Commission established a panel of river ecologists (the Scientific Panel) in 2000 to advise on how best to revise the environmental flow provisions for the lower Ord

River[17]. Given the then limited knowledge of the aquatic environment of the lower Ord, the Scientific Panel proposed a precautionary approach based on keeping sufficient flows in the river to void major changes in downstream aquatic habitat during each dry season. A revised plan incorporating this new approach was drafted by late 2001. However, the proponents selected to develop the M2 Supply Area withdrew in December 2001 and delayed the release of the revised plan.

Additional time was available to study ecological processes and carry out additional investigations of water quality and aquatic biota responses to low flows in the lower Ord River. The following sections summarise the original Scientific Panel advice, additional information gained from the low flow investigations and the interim EWR flow regime that resulted.

3.3.1 Original Scientific Panel advice

The Scientific Panel identified a number of ecological attributes that were important to maintain the health of the lower Ord riverine environment. These included:

- limiting the encroachment of macrophytes and terrestrial vegetation;
- maintaining in-stream habitat for invertebrates and fish;
- maintaining water quality within and between river pools, including the avoidance of diurnal anoxia;
- maintaining adequate connections between pools and river reaches; and
- maintaining carbon and nutrient transport along the river.

Ecological risks to the current riverine environment of the lower Ord River should be minimised if these attributes are maintained. A flow regime that ensures all the attributes are maintained, should also ensure the ecological risks to the riverine environment are low, and, by definition, would represent EWR flow regime for the lower Ord River.

The Scientific Panel considered the most important attribute to maintain was the in-stream habitat available to invertebrates and fish during the dry season. The Commission used a risk minimisation and precautionary approach to the adoption of an initial EWR flow regime for the lower Ord River. It was based on limiting the change in measures of dry season in-stream habitat, as described below, to levels of change considered of low ecological risk.

The Scientific Panel advised that changes in measures of in-stream habitat that were less than 10 per cent would not be significant, changes from 10 per cent to 20 per cent of some concern, and greater than 20 per cent would be of considerable concern to the ecological health of the lower Ord River. These classifications guided

[17] The EPA had recommended this approach.

the Commission's consideration of acceptable change to in-stream habitats and the selection of an initial dry season EWR for lower Ord River.

The amount of submerged river bed and banks (wetted perimeter) provides an overall measure of in-stream habitat. The amount submerged at any one time is, of course, dependent on the river's flow rate. For wide, relatively shallow rivers like the lower Ord, the amount submerged can be approximated by the width of river water. The width of water at specific flow rates can be calculated from hydraulic modelling of the river, using data on the bed and bank shape at cross-sections along the river. The width of water within specific water depth classes can also be determined and grouped by cross-sections with similar bed and flow conditions to form a range of measures of in-stream habitats for specific river reaches.

To guide assessment of an acceptable change to in-stream habitat during the dry season, these measures of in-stream habitat were calculated for a range of likely dry season flows at 51 individual cross-sections along the lower Ord River (see Appendix 3). The widths of shallow (<1 m) and deep (>1 m) water at each flow rate and cross-section, were used as individual measures of in-stream habitat and expressed as a percentage change, relative to the widths at a standard flow rate base, considered typical of dry season flows in the lower Ord River since regulation by the Ord River Dam.

The typical dry season flow rate adopted was the median of average dry season flow rates after Lake Argyle first filled (1974) and was estimated to be at 50 m^3/sec in June 2000.

The individual measures of change were also grouped by river reach and flow-depth characteristics to establish the average change in 12 distinct in-stream habitat classes (shallow and deep water in pools and non-pool sections in three river reaches (Table 6)). These 12 habitat classes were defined to evaluate the change to a range of in-stream habitats likely to be favoured by different age and size classes of fish species and macro-invertebrate communities within the lower Ord River. [18]

The 51 cross-sections[19] showed that the river channel was characteristically U-shaped downstream of House Roof Hill (58 km downstream of the Kununurra Diversion Dam). However, the channel shape between the Kununurra Diversion Dam and House Roof Hill included sections with benches and more gradual side slopes. In consequence, the river width downstream of House Roof Hill changes less as flow rate is reduced than between the Kununurra Diversion Dam and House Roof

[18] The twelve habitat classes were surrogate measures for more specific local habitats, important for maintaining ecological processes and species richness and abundance along the river. Knowledge of such local habitats was not available in 2000.

[19] The 51 cross-sections were surveyed during June 2000 when the flow rate was about 500 m^3/sec. This unusually high dry season flow rate was dominated by continued spillage from Lake Argyle after the very large inflows of the 1999-2000 wet season. Additional water level data at a flow rate of about 70 m^3/sec were available from an earlier study (in 1998) designed to locate the interface between estuarine and fresh river water in the lower reach from Carlton Crossing downstream.

Hill. This observation led to consideration of composite environmental flow regimes that permitted flow rates downstream of House Roof Hill to be 5 m^3/sec lower than the flow upstream of House Roof Hill[20]. Composite environmental flow regimes of this type have the advantage of maintaining higher flows in the parts of the river most sensitive to habitat change and enable up to 5 m^3/sec to be diverted from the lower Ord River downstream of House Roof Hill, without causing excessive in-stream habitat change.

As expected, the number of individual cases of habitat change greater than 20 per cent increased as flow rates/regimes reduced (Table 6). Results from the initial hydraulic model calibration showed that the incidences of habitat change greater than 20 per cent increased substantially at flow rates lower than the 45-40 m^3/sec flow regime (see Appendix 3) and led the Scientific Panel in 2000 to advise that this flow regime should form the basis for an interim EWR for the lower Ord River.

3.3.2 Consideration of subsequent information

Subsequent to the initial development of the interim EWR, additional information and techniques of EWR assessment have become available. Their implications for the interim EWR are discussed in this section. The main factors discussed are:

- comparison of the interim EWR against a higher dry season base flow;
- recalibration of the hydraulic model; and
- capability to analyse all components of the flow regime (i.e. include analysis of wet season flows).

In recent years, dry season flow rates have been higher than the initial base of 50 m^3/sec, as estimated in June 2000. Rates in excess of 50 m^3/sec commenced soon after the Ord Hydro-electric Power Station was commissioned in 1996. By the end of the decade dry season flow rates were typically round 60 m^3/sec and have continued to increase as power demands have grown. To assess the sensitivity of measures of habitat change to the initial base flow rate of 50 m^3/sec, estimates of habitat change were also calculated from the higher flow rate base of 60 m^3/sec. In addition, the hydraulic model of the lower Ord River was re-calibrated in 2003 as part of the investigations related to the low flow trial (see below). Both effects are shown in Table 6 for the 45-40 m^3/sec flow regime. Further detail is included in Appendix 3.

The effect of the 2003 hydraulic model re-calibration was to reduce the amount of habitat change for a given flow rate/ regime. However, the amount of habitat change is increased[21] if measured from the higher flow base of 60 m^3/sec. By interpolation, the habitat change for the 45-40 m^3/sec flow regime, taken from a base of about 55-56 m^3/sec, would be similar to the habitat change estimated originally in 2000.

[20] This enables up to 5 m^3/sec to be diverted from the lower Ord River downstream of House Roof Hill (58 km downstream of the Kununurra Diversion Dam) when the minimum EWR regime upstream is being met.

[21] The rate of habitat change with flow reduction, however, declines if the change is measured from 60 m^3/sec.

In September 2005, the Commission re-confirmed the 45-40 m^3/sec regime as the main dry season element of an interim EWR for the lower Ord River. Being based on the original advice from the Scientific Panel (2000), the decision is considered precautionary. Importantly, the decision was taken in the context of the additional knowledge gained since 2000 (Trayler *et al.*, 2006) and knowing that work was proceeding to establish comprehensive EWR for the lower Ord River to replace the interim EWR.

Table 6 Changes of in-stream habitat for three flow regimes in the lower Ord River

Measures of in-stream habitat change	**Where change is relative to measures of in-stream habitat at 50 m^3/sec**			**Where change is relative to measures of in-stream habitat at 60 m^3/sec**		
Lower Ord River flow regime ‡	**45-40 m^3/sec**	**40-35 m^3/sec**	**35-30 m^3/sec**	**45-40 m^3/sec**	**40-35 m^3/sec**	**35-30 m^3/sec**
No. of cases where the width of river water changes by >20 % †						
Shallow water (<1 m deep)	3 (8)*	8	12	11	15	17
Deeper water (>1 m deep)	4 (6)	6	8	8	10	11
No. of in-stream habitat-depth-flow classes that change by > 20 %††						
Pool habitats						
Shallow water (<1 m)	0 (0)	1	1	1	0	0
Deeper water (>1 m)	0 (0)	0	0	0	0	0
Runs habitats						
Shallow water (<1 m deep)	0 (1)	0	0	1	2	2
Deeper water (>1 m deep)	0 (1)	0	1	1	1	1
Total	0 (2)	1	2	3	3	3

‡ The higher flow rate applies from Dunham River to House Roof Hill (58 km downriver from the Kununurra Diversion Dam). The lower flow rate applies from House Roof Hill to the Ord River Estuary (58 to about 94 km downriver of the Kununurra Diversion Dam)

† Number of cases - 51 cross-sections*2 depths (shallow, deeper) =102

†† Number of habitats –3 reaches * 2 depths* 2 velocity classes (pools, runs) =12

* Values in brackets are the habitat changes calculated in 2000 using preliminary calibration of the river hydraulic model

In addition, as indicated in Section 2.4, the unregulated flows from the Dunham River catchment provide most of the flow variability in the lower Ord River during the wet season. This natural variability is important to maintaining a healthy lower Ord River and can be achieved by excluding further regulation of the Dunham River and its tributaries. This has been included as an additional component to a combined EWR for the lower Ord River and its catchment. Table *7* summarises this overall interim EWR.

The dynamic nature of the riverine environment of the lower Ord River, and the importance of wet season flows to driving the river's ecology, has become increasingly clear in recent years. This has developed from geomorphological and ecological investigations, undertaken primarily since 1999. Trayler *et al. (*2006) have summarised the investigations completed to date. In particular, the magnitude, variability and sequencing of wet season flows has been observed to strongly influence in-channel and riparian flora distribution and local habitats in subsequent dry seasons (Section 2.4; Trayler *et al., 2006*). This has emphasised the limitations of the current dry season habitat methodology and the need to replace it with a holistic approach that includes consideration of all elements of the flow regime including the wet season characteristics.

Table 7 Ecological Water Requirements for the Lower Ord River and catchment

River	**EWR component**	**Period of application**	
River Reach		**When water level in Lake Argyle is**	**Expected % of time**
Lower Ord River			
Dunham River to House Roof Hill †	Minimum monthly flow rate of 45 m^3/sec	>70 m	100 %
Downstream of House Roof Hill	Minimum monthly flow rate of 40 m^3/sec	>70 m	100 %
Dunham River			
Main watercourse and tributaries	No further flow regulation	Not applicable	100 %

† House Roof Hill is 58 km downstream of the Kununurra Diversion Dam

Work is well advanced on completing a comprehensive level assessment of EWR to replace the interim EWR of Table *7*, using the holistic Flow Events Method (FEM) (Stewardson, 2001). When completed the new EWR will be used to assess licenses for Stage 2 developments and will be incorporated in future revisions of this plan.

Additional information on the response of the systems ecology and water quality has also been provided (subsequent to the development of the interim EWR) from low flow trials and modelling conducted in 2002-03. These trials were primarily commissioned to examine the potential response of the system to drought period flows of 35-30 m^3/sec. This drought period flow regime has been incorporated into the interim EWP. The reasons for its inclusion and the implications for environmental values are discussed in subsequent sections.

4 Environmental Water Provisions

4.1 Introduction

In Section 3.1 EWP were defined as “water regimes made available to the environment as part of the Commission’s water allocation decision-making, after considering ecological, social and economic needs for water”. EWP for the lower Ord River form the flow regime to be maintained downstream of the Dunham River confluence after the ecological, social and economic impacts of alternatives have been considered.

As a matter of policy[22], the Department aims to meet all EWR when EWP are proposed. If EWR cannot be met without significantly compromising the economic and social benefits of possible water allocation strategies, then the risks to ecosystems of not meeting the EWR are identified, together with the economic and social costs of fully meeting the EWR, community consultation on the allocation scenarios and EWP options is undertaken, and the proposed allocation strategy referred to the EPA for assessment or advice under the *Environmental Protection Act 1986*.

The following sections provide a summary of social (including cultural) investigations and economic considerations raised during public consultation to develop the interim EWP. The interim EWP, including the drought component, is also discussed as are the potential risks to environmental, social and cultural values.

4.2 Social water values

The social and cultural values that people derive from the Ord River were also considered, in conjunction with the ecological needs, before adopting an appropriate EWP for the lower Ord River.

There is considerable recreational and tourism use of the lower Ord River and people have a strong sense of community identity with the river. The Miriuwung Gajerrong Aboriginal people, in particular, have a strong attachment to the Ord River through their Dreaming and continue to hunt and fish along the watercourse (where access permits). Social values of the Ord River are not limited to within the region, as the Ord River commands considerable status with people who have visited and developed an affinity with the East Kimberley.

Current social values have largely arisen after the irrigation infrastructure was established and the subsequent establishment of the high dry season flows. These have become well established in the years since the Ord River Dam was built.

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[22] Guiding Principle No. 7 of Statewide Policy No. 5, *Environmental Water Provisions Policy for Western Australia* (WRC 2000b)

In recent years, the cultural values that Aboriginal people hold in relation to the Ord River have been documented (Barber and Rumley, 2003). The WA *Aboriginal Heritage Act 1972* and the Commonwealth *Native Title Act 1993* provide a legal means of recognising and protecting traditional interests of Aboriginal people. During the period of development of this plan, Native Title claims by the Miriuwung Gajerrong people were before the courts and covered, in part, land relating to Stage 1 and Stage 2 Areas of the Ord Irrigation Project. These claims were eventually settled by negotiation with the WA Government (in 2005), the outcomes of which are described in Section 4.2.2. The importance that Miriuwung Gajerrong traditional owners place on different flow regimes of the lower Ord River are discussed in the context of social water values described below.

4.2.1 Community workshop

A Community Reference Panel was established to identify the social values of the lower Ord River in 2000. Representation was drawn from local government, farming, environment, tourism, recreational and Indigenous interests (Appendix 4). The role of the Community Reference Panel was to provide advice to the Commission in the development of interim EWP. Due to anticipated time constraints the Panel met at a consultative workshop in June 2000[23].

Representatives were briefed on the Scientific Panel recommendations with respect to ecological objectives for the lower Ord River. The workshop identified a range of social values and made recommendations for maintaining those (Appendix 4). The key social values and recommendations are summarised in Table 8.

Participants confirmed that a wide range of social and cultural values should be considered in decisions regarding water allocations for the Ord River.[24] As a result of considering possible future under full Stage 2 development at five designated river reaches of the Ord River, the workshop recommended that water levels and flows could be maintained at current or slightly lower flows to satisfy most values and activities. The workshop expressed a range of views about the degree to which lower flows would be acceptable. Recommendations ranged from maintaining a minimal depth of 0.6 m downstream of Tarrara Bar at all times to facilitate boat passage through to Cambridge Gulf, to making provision for average flows only. The latter recognised that permanent or continuous passage may not be achievable if other (economic) benefits were also to be achieved.

[23] A follow up seminar was held in October 2000 to present information on the proposed allocation strategy at the time and panel representatives were encouraged to provide written comment (see Appendix 2, A2.2).

[24] At the time of the June workshop the revised draft plan was proposed for release in October 2000. Had the additional time before release of the revised draft plan been known at the time (a consequence of additional technical work and review of options that became necessary), a different approach to the consultation process would have been undertaken. Instead, consultation and negotiation has focused on issues relating to specific stakeholders and on development of a communication and involvement process during the interim phase of the plan, leading up to the replacement of the interim plan (see Section 10.2).

Appendix 4 provides detail of the views expressed in relation to particular values and locations along the lower Ord River. For example, representatives of traditional owners indicated that access to the river for fishing and ceremonial activities were important to Aboriginal people, and suggested short periods of dry out and wash out. Subsequent discussions with traditional owners confirmed that having access to the river so they can pursue their traditional activities associated with the river, was important to Aboriginal people (Barber and Rumley, 2003). Individual members of the Community Reference Group also expressed interest in a comprehensive costs/ benefit analysis to identify the value of the trade-offs between environmental, economic and social uses of river water.

Table 8 Recommendations of the June 2000 community social values workshop

Social Value	Overall Recommendations
Water Quality	• There needs to be some flow maintained throughout the year. The level of flow may be less than the current flow as long as water quality can be maintained.
Economics	• Water availability must be maintained but the requirements of the environment, tourism and power demand are acknowledged. • For most forms of tourism and for other economic uses such as pastoralism and aquaculture, a reduction in flow is acceptable, as long as some flow is maintained. • Recommendation that flow should be maintained at the current levels for the purpose of boat-based tourism[†]. Ensure a minimum depth of 0.6 metres below Tarrara Bar, at all times. • Some river reaches may be seasonally limited and water should be provided for average flows, not for permanent or continuous passage. This will require changes in the management and operation of boat-based tourism enterprises, in terms of timing and location of operations.
Social and Aesthetic	• To maintain some water flow at the shallowest bars throughout the year. The level of flow may vary from the current flows to the lower flows predicted under Stage 2 Supply Area.
Environment and Habitat	• Recommendations ranged from maintaining current flows to a recommendation that full Stage 2 Supply Area allocations proceed because no environmental impacts were expected. The need for some further work, such as that recommended by the Scientific Panel, was acknowledged.
Traditional Ownership	• Lower flows are acceptable but further consultation needs to be undertaken with traditional owners.

[†] This recommendation was supported by only two delegates. The majority recognised that water was also needed for the environment, power production and irrigation development.

In general, there was strong similarity between the Community Reference Group recommendations and those of the Scientific Panel. This was particularly true in the need to maintain dry season flows at a level that would avoid reduction in water quality and other ecologically adverse impacts. Also similar were recommendations for further investigations and information. Both groups recommended further hydrological and sediment studies and studies of the relationship between volume, flow and water levels along the lower Ord River. Most of these aspects have been addressed in subsequent work (Trayler *et al;* 2006, Appendix 3).

The Ord Land and Water Management Plan (OLWP) was released in 2000 (Ord Land and Water, 2000) and presented community aspirations in relation to land and water management in the Ord River Irrigation Area. The River Issues section demonstrated that the community valued the lower Ord River and recognised that an informed assessment of ecological water requirements for the lower Ord River needed to be balanced with the needs of recreational uses and commercial uses including power and irrigation. The OLWP included management strategies to maintain these values and advocated an overall River Management Strategy.

As part of the Commission's consideration of economic aspects in guiding water allocation decisions, the non-agricultural benefits (tourism and recreational benefits) arising from the dry season flow regime of the lower Ord River were estimated at approximately $5 million/yr (see Table 9) in 2000, or about 10 per cent of the current irrigated agricultural production. Also included for comparison are estimates of tourism and recreational benefits generated from the irrigation infrastructure and reservoirs of the Ord Irrigation Project. These have a high profile with both the local community and visitors, as Kununurra acts as the eastern gateway to a range of Kimberley tourist and recreational destinations. Visitor surveys indicate 22 per cent of visitors purchase a river cruise and 26 per cent go fishing. Fifty per cent of local residents report they spent 19.6 days fishing each year of which half is spent in the lower Ord River area.

4.2.2 Aboriginal cultural values

Since the initiation of the first stage of the Ord Irrigation Project the recognition of cultural values of the river system has gained greater significance within the community and under our legal system. In addition to informal discussions with traditional owners noted in Section 4.2.1 above, a specific study was commissioned to establish, record and articulate the cultural values[25] that Aboriginal traditional owners and communities attach to the Ord River (Barber and Rumley, 2003). Because the waterway has already been modified, some of the cultural values have changed or been lost. Consequently, as well as providing input to the EWP assessment, the study acknowledged lost or changed values, and indicated Aboriginal interest in contributing to future waterway management and related policies and plans.

The study focused on downstream from Lake Argyle to the Lower Ord River, and covered the river's floodplain and wetlands (see Figure 12). Traditional owners with knowledge of and interests in the area were engaged during the fieldwork period and various locations along the Ord River were visited with these people. They were able

[25] Values include cultural, environmental, social and economic values that are expressed in the relationship and interactions between Aboriginal people and Ord River ecosystems.

to discuss, articulate and record their associated cultural, social and economic values, including religious beliefs and environmental knowledge as indicated in the relationship and interactions between themselves and the Ord River ecosystems. Discussions included reference to ecosystems within the Ord River valley both in the pre- and post-dam contexts. Site protection and minimising or avoiding impacts on Aboriginal cultural values within the study area were also discussed, as were approaches by which these might be achieved.

Table 9 Economic activity generated by the Ord River Irrigation Project†

Economic activity by sector and product or service (gross value of production or costs incurred in carrying out the activity)	**$million/yr**
Irrigated agriculture --Stage 1 areas[1]	56
Irrigated agriculture --Stage 1 areas (with planned growth)[2]	110
Horticulture & other crops (7,000 ha)	82
Sugar cane growing (9,000 ha @ $26.25/tonne)	28
Water related activities- based on Lakes Argyle and Kununurra and the project area	10
Extended stays to visit the project area and infrastructure[4]	7.0
Lake tour operations	1.0
Incremental tourism directly associated with lake touring	1.5
Commercial fishing	0.8
Water related activities- based on the lower Ord River	5
Recreational fishing, local and tourist[5]	1.7
Fishing charter operations	0.9
Incremental tourism associated with fishing activity	2.0
Food gathering by Indigenous people	0.1

† Adapted from King *et al*., 2001
1 The gross value of production averaged over last six years to 2005
2 Projections were initially made in 2000 and used 2000 prices, except for sugar. A sugar price based on the 2004 projection at the Outlook 2000 conference was used to reflect the long term sugar price
3 Includes expected production from planned growth in the irrigated area (to 15,000 ha)
4 Based on tourists staying one extra day in Kununurra to see the project area and Lakes Kununurra and Argyle
5 Based on fishermen spending an average of $42/day

Broadly, Aboriginal people have a strong desire for improved recognition of Aboriginal rights of access and expectations of a role in management. People in the region have a strong association with the river and do not separate water from country. They have a responsibility for looking after their country through their "conception spirit" that defines a group's location and extent. The Aboriginal belief system is centred on the Dreaming, which started when the land was flooded and continues to the present. The Dreaming are events that created the soils, water, places and culture and define timeframes. Aboriginal people learn about the Dreaming throughout their lifetime and many of the spatial and temporal cues to their stories and songs have been affected by irrigation development and changes to the hydrology of the river. While the Dreaming is less visible since irrigation development, the culture remains and Aboriginal people also attribute values to today's environment. Specific issues that arise in relation to river management are accessibility, predictability of flow, estuarine crocodile movement and water quality. Aboriginal people in the region take a long term view of planning and want a role in management

These points were reinforced in March 2004, when the Kimberley Land Council documented the social and economic impacts that Stage 1 of the Ord River Irrigation Project has had for the Miriuwung Gajerrong peoples (Kimberley Land Council, 2004). The report highlighted the disregard for Aboriginal views when the Irrigation Project was initially developed, the limited efforts to seek Aboriginal views until very recently and the Miriuwung Gajerrong people's desire to become involved in land and water management in the future.

4.3 Native Title issues and the Ord Final Agreement

In December 2003, the Federal Court ratified an agreement between the WA Government and the Miriuwung Gajerrong and Balangarra people that recognised their traditional rights in the lower Ord River area. This recognised Native Title on the WA side of the border and resolved a series of court decisions and appeals stemming from the first Native Title claim made by the Miriuwung Gajerrong people in the 1990s.

Following further negotiations over a benefits package and compensation for access to land required for Ord Stage 2 developments in Western Australia, the Ord Final Agreement was signed in October 2005 (Office of Native Title, 2005). This is an agreement between the WA Government and their land and conservation agencies, the Miriuwung Gajerrong people and their representative bodies, and relevant pastoralists. The agreement resolved Native Title and Aboriginal heritage issues over land proposed to become irrigated farmland under Ord Stage 2 developments in WA, while enshrining the right of the local Aboriginal people to participate in, and benefit from, investment associated with the expansion of irrigated agriculture in the East Kimberley.

The Agreement enables approximately 65,000 ha of land to be released for agricultural, industrial and residential development, and includes buffer areas around the new agricultural land. It also provides for a further 154,000 ha of conservation land, to be established in six new conservation parks. The Agreement includes a range of initiatives for the benefit of Miriuwung Gajerrong people, with a total value of $57 million. These initiatives focus on developing the capacity of the Miriuwung Gajerrong people to engage in the local economy and benefit from any future development. Importantly it also includes financial support for improved land management, to be carried out in conjunction with the Miriuwung Gajerrong people.

4.4 An interim EWP for the lower Ord River

4.4.1 Balancing recreational, cultural, operational and ecological aspects

As noted in Section 4.2.1, recreational and ecological water needs for the lower Ord River are largely compatible. Maintenance of the 45-40 ^{3}/sec interim EWR flow regime is considered sufficient to meet most recreational and tourist water needs during the dry season. Some recreational fishers currently experience difficulty in navigating boats through shallow sections of the river, especially around Mambi Island, downstream of Carlton Crossing. While the 45-40 m^3/sec interim ecological flow regime will result in slightly lower depths of flow than the historic base of 50 m^3/sec, any decrease in navigability will be marginal and considered manageable (see Section 3.3).

The Dreaming of the Miriuwung Gajerrong people include stories associated with the pre-dam flow regime of the lower Ord River and, as noted earlier (Section 4.2.1), Miriuwung Gajerrong elders suggested a drying out period of lower flow during the dry season. Unfortunately, it is not possible or desirable to re-establish the pre-dam flow regime. As described previously (Sections 1.2.3, 3.2, and 3.3), advice from the EPA and Scientific Panel established the priority on maintaining sufficient dry season flows to protect the current ecological and social values of the lower Ord (Sections 3.3 and 4.2).

Nevertheless, since the early 1990s there have been four occasions when short periods of low flow (usually of two to five days duration) occurred in the lower Ord River at the end of the dry season. They were associated with maintenance and inspection work on the Kununurra Diversion Dam and other man-made structures downstream or, in the last case, the low flow trial of 2002. The need to inspect these structures again, albeit infrequently, will occur in the future.

The task of planning and implementing a future short term low flow maintenance period should not be under-estimated, given the range of interested stakeholders and the competing objectives. This is an aspect being considered as part of developing comprehensive EWR and EWP for the lower Ord River and is not part of this current plan. However, the following aspects will need to be considered as part of planning of future short low flow maintenance periods. Under the Ord Final Agreement, the Miriuwung Gajerrong people expect to be involved in resource management decisions that affect their country. Traditional owners should contribute to planning future low flow maintenance periods so they have an opportunity to use such times to promote learning of dreamtime stories and other traditional practices. While relatively rapid declines in flow rate will be required to achieve the maintenance objectives, these should be limited to the extent possible, so that the adverse effects on the aquatic biota observed during the low flow trial are minimised. Future maintenance periods should be in-frequent (say no more frequent than an average of one in five years), to minimise the additional pressures placed on the river ecology. Except for emergencies, they should be separated by at least three years so that there is sufficient time for the riverine environment to recover.

4.4.2 Adoption of an interim EWP regime

When the interim EWR regime was initially discussed with the local community in 2000, licensees and commercial water users raised objections to the severity of their restrictions needed if the 45-40 m^3/sec EWR were maintained during drought periods. This led to an evaluation of whether a reduction to a flow regime of 35-30 m^3/sec in 5 per cent of years would be an acceptable increased risk to the lower Ord environment and how much additional water would be available to reduce the severity of restrictions at such times of shortage.

Reservoir simulations were undertaken to determine the severity of irrigation restrictions when the flow maintained in the lower Ord River was reduced by 10 m^3/sec, when the storage in Lake Argyle reached critically low levels about 5 per cent of the time. Table 10 shows the water supplied during the three most severe restriction years in the 86 years simulated, for the two cases where the drought period reduction is and is not included in the EWP. Results are presented for the case where the irrigation allocation from Lake Kununurra was approximately 750 GL/yr. The simulations reduced the EWP by the 10 m^3/sec for five to seven months of lowest storage in the three years in question, making an additional 100 to 150 GL/yr available for diversion. For the most extreme year of 1934-35, the additional available water reduced the level of restriction from a severe 35 per cent, to 56 per cent of the irrigation demand (Table 10).

Table 10 Effect of the drought period EWP on the severity of water restrictions

Case	**45-40 m^3/sec -No drought period EWP**				**Drought period EWP – 35-30 m^3/sec**			
	Water supplied during restrictions †				**Water supplied during restrictions †**			
Severity of restriction year- (Rank)	**Stage 1 GL**	**M2 Area GL**	**Total GL**	**Total - as % of demand**	**Stage 1 GL**	**M2 Area GL**	**Total GL**	**Total - as % of demand**
1	124	131	255	35 %	195	213	408	56 %
2	134	139	274	37 %	194	208	402	54 %
3	166	181	347	49 %	212	233	445	62 %

† Average water allocation from Lake Kununurra: Stage 1 = 350 GL/yr, M2 Supply Area = 405 GL/yr

The financial return to growers in years with restrictions is obviously affected by the severity of restrictions. The more severe the restrictions, the greater the negative financial and economic impact. However, the impact is not likely to be directly proportional to the water available. Some crops produce reasonable yields when water is in short supply, provided the shortfall is not excessive. Sugarcane for example, tends to reduce its biomass in proportion to the water available, but its sugar yield tends to reduce more gradually, provided that the water applied is at least 60-70 per cent of the optimum. Consequently, in years when the water available is restricted to 56 per cent to 62 per cent of allocation, only mild to moderate yield reductions would be expected. Cane growers could be expected to cover costs or make small losses in such years. However, in years when the water available is as low as 35 per cent of the allocation, major losses could be expected. Yields would be significantly affected and growers would be forced to hold off replanting at least 50 per cent of their harvested areas until additional water became available. This would cause disruption to cropping rotations and affect incomes in subsequent years.

Given the above, significant reductions in the economic and social costs of restrictions would be expected by adopting the proposed drought period EWP. Appendix 3 describes the potential impacts and risks to the riverine environment from the lower flows of the drought period EWP. Overall, the ecological risk to the river environment was considered low and any impact on aquatic fauna populations during the drought period should be able to recover in the 95 per cent of years when the full interim EWR is maintained.

Consequently, the Commission considered that the benefits from reduced restriction costs more than off-set any increased risk to the lower Ord River environment, and adopted the interim EWP flow regime as detailed in Table 11.

Table 11 Interim environmental water provisions for the lower Ord River

River *River Reach*	**EWP component**	**EWP flow rate** m^3/sec ‡	**Period of application**	
			When water level in Lake Argyle is	**Expected in % of years**
Lower Ord River				
Dunham River to House Roof Hill	Non-drought period	45	>76 m	95 %
	Drought period	35	<76 m	5 %
Downstream of House Roof Hill	Non-drought period	40	>76 m	95 %
	Drought period	30	<76 m	5 %
Dunham River				
Main watercourse and tributaries		No further regulation	Not applicable	100 %

† House Roof Hill is 58 km downstream of the Kununurra Diversion Dam
‡ Minimum monthly flow rate

Although the interim EWP has included the drought period provision, it is highly unlikely that it will be triggered in the next three years (the expected lifetime of this plan). Based on July 2006 levels in Lake Argyle, inflows for the next three wet seasons would need to be the lowest on record (since 1906-07) for lake levels to reach 76 m AHD. The probability of this occurring is less than 1 per cent.

As indicated in Section 3.3.2, a comprehensive assessment is being undertaken to update the interim EWR, based on the Flow Events Methodology of Stewardson (2001). This work is well advanced and will be used to guide revision of the interim EWP and allocations in this plan over the next two to three years (see discussion paper).

5 Commercial water demands

This section presents projections of future irrigation and hydro-electricity demands likely to be supplied from the Ord River water resource. Maximum likely demands (expected to develop over the next 20 years) and demands expected to develop over the next three years (the intended life of this plan) are provided.

5.1 Factors affecting irrigation demand

Factors affecting the irrigation demand in an irrigation area supplied from a surface water source include the following:

1. the total area expected to be irrigated in a normal (non-restriction) year within the total supply area serviced by the distribution system;
2. the expected area of crop types and their crop water requirements[26];
3. the irrigation water requirement for each crop type[27] ;
4. any leaching factor required to avoid salt accumulation in the crop root zone;
5. losses in delivering water from the farm gate to the roots of the crop; and
6. distribution losses between the point of diversion and the farm gate.

In reviewing the irrigation water requirements of the current and proposed irrigation supply areas, the Commission carefully considered each of the above factors. In doing so, it took advice from Agriculture WA, and information from the current and proposed irrigators, their consultants and operators of other irrigation districts in Australia. The projected demands and assumptions used are outlined below. Further details are provided in Appendix 5.

5.2 Stage 1 irrigation demands

5.2.1 Areas supplied by the Ord Irrigation Co-operative

The irrigation water demand for the area supplied by the Ord Irrigation Co-operative (OIC) has been assessed as 333 GL/yr (rounded to 335 GL/yr) under average rainfall conditions. Details of the crop areas and distribution efficiencies used to assess the demand are given in Table A5.1 of Appendix 5. Provision was made for additional land to be developed (Green Location (1,200 ha)), the total irrigated area to reach 14,570 ha and for the area of sugarcane to increase to approximately 9,000 ha[28]. The additional area and increased area of sugarcane were to come from a

[26] The quantity of water required by the plant to grow without being limited by available soil water. This is a function of the crop type, the moisture holding properties of the soil and the evaporative demand. It can be supplied from rainfall or irrigation applications or both.

[27] Being the crop water requirement minus the water that can be supplied from rain fed soil moisture- a function of the rainfall and soils in the irrigation area.

[28] The Cheil Jedang Corporation acquired the Ord Sugar Mill in Kununurra from CSR during 2000 and have indicated their intent to upgrade raw sugar production capacity to at least 1.0 mt/yr. This capacity is considered the smallest likely to be viable based on recent experience of mill closures in Queensland. Using

combination of new land development, some sugarcane replacing other existing crops and an increase in the area irrigated within existing farm blocks. The 335 GL/yr demand was based on a target distribution efficiency of 80 per cent.

The irrigation water demand in any particular year is dependent, in part, on the rainfall that falls over the irrigated area in that year. In over 90 per cent of years, the quantity needed should lie within ±10 per cent of the average (335 GL/yr). In years with extremely high or low rainfall, the water demand can be ±15 per cent of the average. Variations in monthly irrigation demands based on variations in monthly rainfalls were incorporated in the reservoir simulations described in Sections 6 and 7.

Table 12 presents the water diverted and supplied on-farm by the OIC in 2003-04 and 2004-05.[29] Also shown are the distribution efficiencies achieved. In recent years the area under irrigation has been approximately 12,000 ha, with approximately 4,000 ha being planted to sugarcane. While these areas are significantly lower than adopted when assessing the average irrigation demand, the volume diverted (approximately 310 GL/yr in each year) has been within 10 per cent of the estimated average demand. The discrepancy is explained by the low distribution efficiencies achieved during the 2003-04 and 2004-05 water years.

current crop yields from the area, approximately 9000 ha of cane would need to be irrigated each year to provide the necessary feedstock.

[29] The quantities supplied on-farm since the Ord Irrigation Project commenced are presented in Appendix 1.

Table 12 Water use by the Ord Irrigation Co-operative – 2003-04 and 2004-05

	2003-04 Water Year			**2004-05 Water Year**		
	Wet Season	**Dry Season**	**Total**	**Wet Season**	**Dry Season**	**Total**
Water diverted at	GL	GL	GL	GL	GL	GL
the M1 Offtake	95.8	196.5	292.3	89.5	188.8	278.3
the Packsaddle PS	4.1	15.6	19.8	6.5	21.8	28.3
Total	99.9	212.1	312.0	96.0	210.6	306.6
Water supplied on-farm via						
the M1 Offtake	27.1	114.7	141.8	49.4	124.7	174.2
the Packsaddle PS	1.7	11.9	13.6	3.8	16.6	20.4
Total	28.8	126.6	155.4	53.2	141.3	194.6
Distribution Efficiency						
Supplied via the M1 Offtake	28.3 %	58.4 %	48.5 %	55.2 %	66.1 %	62.6 %
Supplied via the Packsaddle PS	41.3 %	76.0 %	68.6 %	58.7 %	76.1 %	72.1 %
Total	28.8 %	59.7 %	49.8 %	55.5 %	67.1 %	63.5 %

Water Year – 1st November to 31st October; Wet season – November to March, Dry Season – April to October

As discussed in Section 8.4.1, the OIC have been set a target of reaching a dry season distribution efficiency of 80 per cent by the end of their current licence period (2008). The demand is expected to remain at or below 335 GL/yr, under average rainfall conditions, while the area under irrigation and sugarcane increases, and improvements in distribution efficiencies are progressively achieved over the next three years. The OIC demand is not expected to change significantly in the longer term, although the assumptions used in its estimation will be reviewed when the OIC licence is being assessed for renewal.

5.2.2 Self supplied demand

The Department considers that 14 GL/yr (rounded to 15 GL/yr) would be sufficient to meet the water demand of irrigators who pump direct from Lake Kununurra or the Ord River in first 15 km downstream of Kununurra Diversion Dam over the next three years. Provision for short term growth has been included in response to submissions made at the October 2000 Community Reference Panel Workshop (Appendix 4). The areas used, crop water needs and calculations are listed in Table A5.2 and are based on the same approach as used for OIC's Supply Area with the following differences. Irrigation water requirements are marginally different for some crop types because soils and rainfall effectiveness are different. The largest difference is in the estimated distribution losses between the point of diversion and the application point(s) within the farm. As these are generally simple piped systems, a loss of 5 per cent has been estimated to the end of pipe compared with the 20 per cent loss in the channel distribution systems.

Self supplied diversions are also made for public and commercial purposes in Kununurra. Current use for these purposes is about 0.3 GL/yr and is expected to increase as the town grows. However, demand is unlikely to exceed 1 GL/yr in the short term.

5.3 Stage 2 irrigation demands

5.3.1 The M2 Supply Area

The M2 Sugar Project

In January 2000, a joint venture of Wesfarmers, Marubeni Corporation and Water Corporation, the preferred developers for the M2 Supply Area released their Environmental Review and Management Program (ERMP) on their M2 Sugar Project for public comment and review by the EPA (Kinhill, 2000). The developers proposed establishing 29,000 ha of sugarcane on 32,000 ha of serviced irrigation land known as the M2 Supply Area. The ERMP included an irrigation demand of 740 GL/yr for the M2 Supply Area and commitments to apply best irrigation practices and active groundwater management, to minimise the environmental impact of the project.

Further details of the M2 Sugar Project and background on the developers' decision to withdraw from their project in December 2001 are given in Appendix 1.

Maximum likely demand of the M2 Supply Area

At the time that the developers withdrew, the environmental assessment process was well advanced. The WA and NT Governments remained committed to developing the M2 Supply Area, and the WA Minister for State Development accepted responsibility as caretaker proponent[30] for the development. In February and March 2002, the respective Ministers for the Environment of the WA and NT Governments gave conditional environmental approval to an irrigated agricultural development over the M2 Supply Area. The Ministers agreed with the EPA to limit the area to 30,500 ha and set formal conditions on the development in January (WA Minister) and March 2002 (NT Minister). The mix of crops proposed and water allocation to be used in the development was not part of the assessment, although conditions on the management of the diverted water were defined. The

[30] As defined in the *Environmental Protection Act 1986.*

environmental impact of the diversion will be assessed, through advice on this plan and at the time a new proponent seeks a licence to divert water under the provisions of RIWI Act. The environmental approval for the project was conditional on the proponents' implementing their initial commitments, additional commitments negotiated during the environmental review process and the completion of some more detailed studies, before and during the final design stage (Minister for the Environment and Heritage, 2002; EPA, 2001). Importantly, from a water demand perspective, the EPA considered that the Project Area should be reduced to about 30,500 ha, to exclude specific areas that contain important vegetation communities necessary for biodiversity conservation.

The reduction in area reduced the maximum irrigation demand for the M2 Supply Area to 692 GL/yr (rounded to 690 GL/yr). This quantity of water enables 28,200 ha[31] of sugarcane to be grown, being limited by water, under median annual rainfall conditions, throughout the M2 Supply Area (based on a gross farm area of 30,500 ha[32]). The assumptions used in the estimate are detailed in Table A5.3. The approach used to assess the Stage 1 demand was taken, although higher on-farm and distribution efficiencies were adopted to reflect the inclusion of on-farm recycling and a balancing storage as conditions of the development.

Other broad acre irrigation crops likely to be grown in the M2 Supply Area have lower crop water demands than sugarcane. Therefore, the 690 GL/yr demand estimate is considered the upper limit of irrigation demand for the M2 Supply Area.

Maximum demand of the Western Australian portion of the M2 Supply Area

In October 2006 the WA Government sought private sector interest in developing between 7,000 ha and 16,000 ha of the M2 Supply Area within WA (see Section 1.2.4). Depending on the time to select the new proponent, obtain final environmental and other approvals, and construct the necessary infrastructure, the additional land could be available for irrigation in 2009.

The maximum likely water demand under the 16,000 ha option is expected to be no greater than about 360 GL/yr, and certainly would not be greater than 400 GL/yr. The crop water requirements and other assumptions used are described in Section A5.2 of Appendix 5.

The actual amount of water required will depend on the mix of crops proposed and the final areas of farmland to be developed.

31 Advice from the Dept. of Agriculture is that about 92.5 per cent of the total farm area can be planted to sugarcane, when row lengths of 500 to 800 m are used (as per the ERMP) and adequate provision is made for on-farm infrastructure.

32 Further investigations have subsequently reduced the area likely to be developed to 30,060 ha.

5.3.2 Development areas downstream of the Kununurra Diversion Dam

In assessing water demand from potential irrigated areas downstream of the Kununurra Diversion Dam, the Department considered future development scenarios originally proposed by the Ord Development Council and Agriculture WA in 2000. These include development of all the suitable soils downstream of the Kununurra Diversion Dam and therefore represent maximum likely demand scenarios. The estimated additional downriver demand under the scenarios totalled 148 GL/yr, under average rainfall conditions. This would be sufficient to irrigate 10,615 ha of crops within a gross farm area of about 11,800 ha. Details of the assumptions made are given in Table A5.5 (Appendix 5). The table distinguishes short term demand growth (incorporated in the Stage 1 estimates), from the longer term developments downstream of the Kununurra Diversion Dam (see footnote to Table A5.2).

Since the scenarios were formulated, the Ord Final Agreement and the Wyndham East Kimberley Shire’s Local Planning Strategy have been completed. These signal changes to how downriver developments may proceed in the future. However, downriver demand is not expected to exceed the 148 GL/yr maximum noted above.

5.4 In-stream demands

5.4.1 Electricity demands

Since 1996, Pacific Hydro Pty Ltd’s ORDHP Station has generated over 90 per cent of the electricity demand in the region. The demand is composed of two distinct components: an industrial demand from the Argyle Diamond Mine and processing plant and a retail demand from the towns of Kununurra and Wyndham. As projections of each component are significantly different, they are discussed separately.

The towns of Kununurra and Wyndham

Horizon Power (previously Western Power) retails electricity to customers in the towns of Kununurra and Wyndham. Pacific Hydro Pty Ltd generates over 98 per cent Horizon Power (wholesale) electricity needs at the ORDHP Station, transmitting the electricity to Kununurra for distribution by Horizon Power. Horizon Power operates backup diesel and gas fired power stations in Kununurra and Wyndham to supply the remaining 2 per cent.

Horizon Power’s future power demand is driven by the economic growth in the East Kimberley region and particularly the population growth of Kununurra and Wyndham. Two factors will strongly influence future population in the East Kimberley. The first is Rio Tinto’s decision (December 2005) to continue underground operations at the Argyle Diamond Mine until 2018 and source their work-force from the region (principally Kununurra). This will directly impact on future town growth and increase

Horizon Power's electricity demand. The second is the timing and speed with which new Stage 2 developments proceed. Prospects for this occurring in the near future increased significantly with the signing of the Ord Final Agreement in October 2005. In October 2006, the WA Government called for Expressions of Interest from the private sector to develop the WA portion of the M2 Supply Area. Depending on progress with selecting a successful developer and final approvals, construction of the new M2 Supply Area may commence in 2008.

As part of a regional power supply study carried out in 2005[33], Horizon Power demands were projected under two future scenarios; the first assumed that the M2 Supply Area proceeded in stages from 2006 to 2014, and the second assumed no M2 Supply Area development. Both scenarios assumed that the underground Argyle Diamond Mine operation proceeded. Projected growth rates from 2005 were estimated at 4.5 per cent per annum for the Argyle Diamond Mine underground operations without M2 Supply Area development, and 6 per cent with the M2 Supply Area development. Current growth is approximately 3 per cent and is being used by Pacific Hydro Pty Ltd to investigate options for upgrading the ORDHP Station to meet more of the expected total regional demand.

For the purposes of this plan, an underlying growth rate of 3 per cent was adopted to account for the effect of Argyle Diamond Mine's underground operation. Additional growth rates expected from Stage 2 Supply Area irrigation expansion were revised to reflect staged development from 2009 to 2020-21. The additional growth rates varied between years depending on the areas under development. These ranged between 0-6 per cent and averaged 1.2 per cent over the 16 years of projected demands. The projected annual demands of the two scenarios are shown in Figure 13.

[33] The study was commissioned by DoIR, KDC and Western Power (now Horizon Power) to consider options to increase the generating capacity in the region to meet the growing demand, especially if Argyle Diamond Mine continued operations.

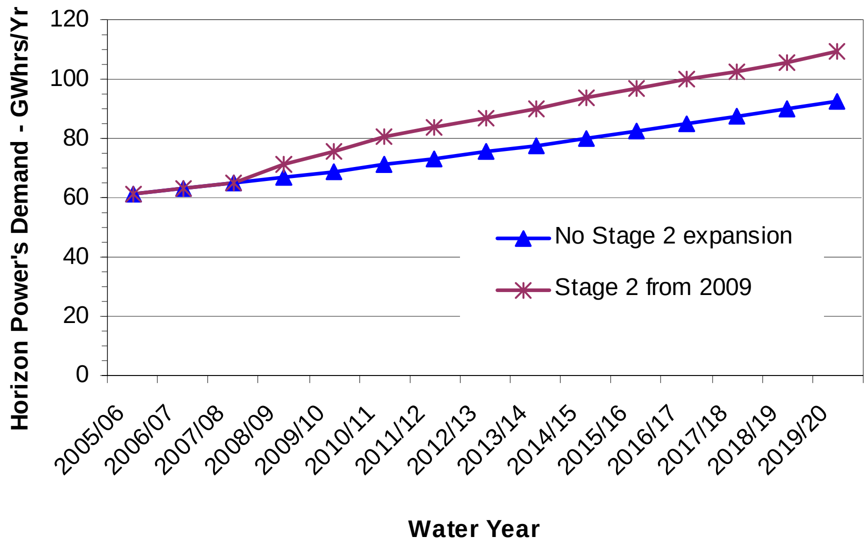

Figure 13 Projections of Horizon Power's electricity demand to 2020

Projected monthly demands are expected to have a similar seasonal distribution as the current demand. These tend to peak in October and November in the build up to the wet, when levels in Lake Argyle are at or near their seasonal low.

The Argyle Diamond Mine and processing plant

Prior to the construction of the ORDHP Station, Argyle Diamond Mine supplied all its electricity needs from its own diesel power plant at the mine site (140 to 160 GWhrs/yr). Since 1996, Pacific Hydro Pty Ltd have generated and transmitted over 90 per cent of the demand to the mine site, with the Argyle Diamond Mine diesel power plant providing the remainder.

When the Argyle Diamond Mine was originally planned, open cut operations were expected to end around 2003 when the alluvial ore deposits were mined out. Investigations commenced into the feasibility of reconfiguring the mine as a deep underground operation in 2002. Feasibility studies progressed over the subsequent years, while the remaining alluvial deposits and an initial (lateral) underground shaft were mined. Different deep underground mining approaches were evaluated, and electricity demands assessed and revised periodically (usually upwards). With the decision to proceed with deep underground operations in December 2005, mine planning entered a design phase and future electricity demands firmed. Figure 14 presents June 2006[34] estimates of the mine and processing plant's electricity demand to December 2018, the expected life of the underground mine.

The electricity demand of the underground operation is projected to be around 240 GWhrs/yr for much of the next decade (maximum of 243 GWhrs in 2011-12). This is about 80 GWhrs/yr higher than the demand of the alluvial mining operations

[34] These were provided by Argyle Diamond Mine via Pacific Hydro Ltd.

and is a result of additional ventilation, refrigeration and ore handling loads of the underground operation.

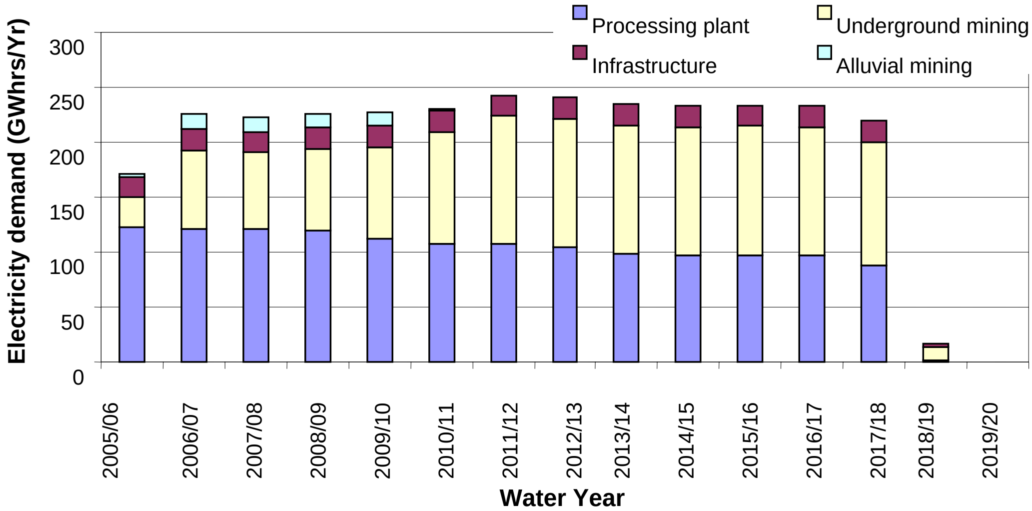

Figure 14 Electricity demand projections for the Argyle Diamond Mine

5.4.2 Meeting the growing electricity demand of the region

Figure 15 shows the combined Argyle Diamond Mine and Horizon Power projected electricity demands, assuming that Stage 2 Supply Area irrigation developments proceed from 2009. The annual electricity demand is expected to exceed 325 GWhrs/yr by 2011-12, and remain around or above this level until 2018-19. Annual demand is expected to peak in 2016-17 at 333 GWhrs/yr. The seasonal distribution of demand for the 2011-12 water year is shown in Figure 16.

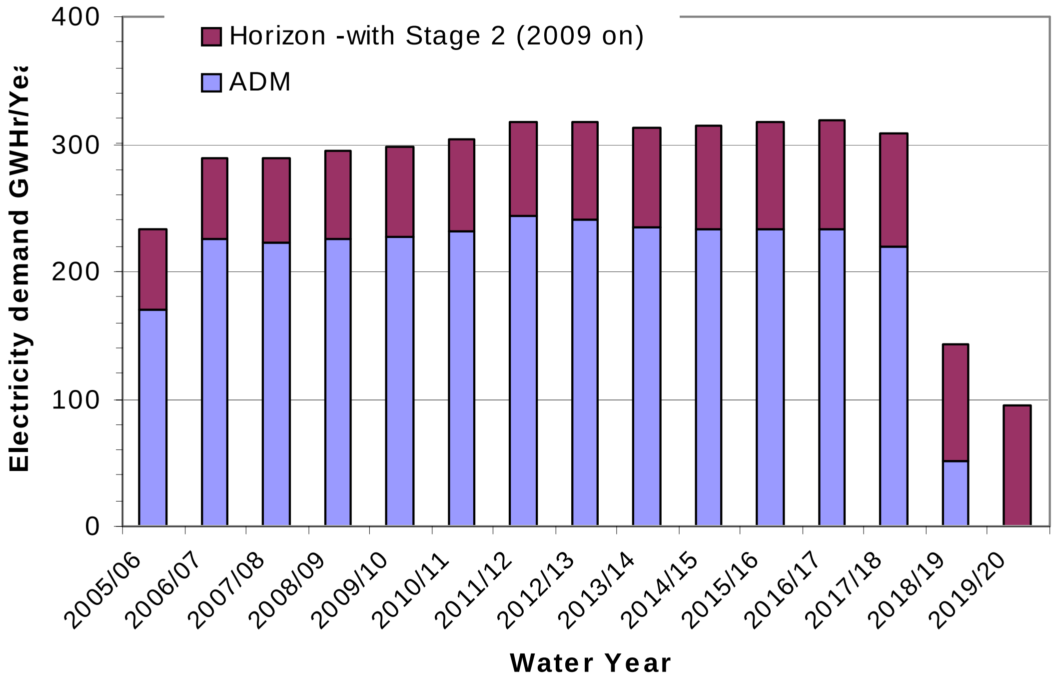

Figure 15 Regional electricity demand projections to 2020

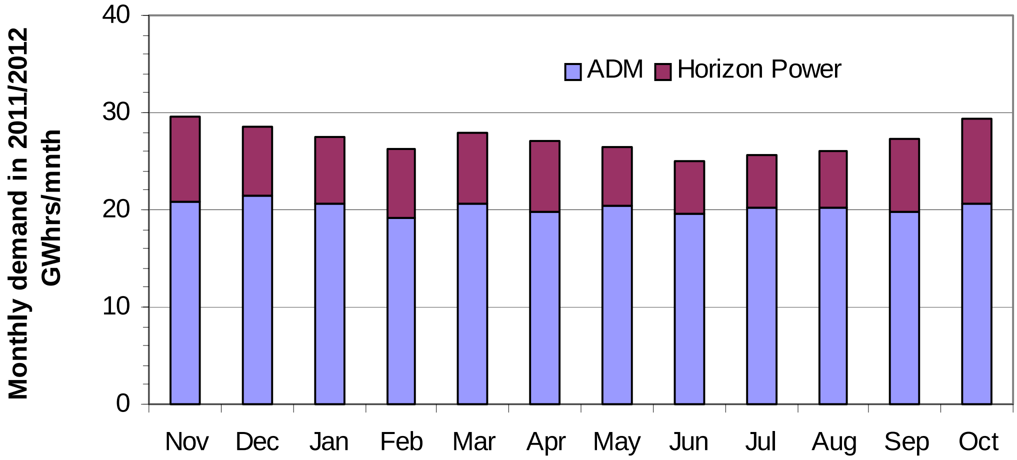

Figure 16 Expected seasonal distribution of demand for the 2011-12 water year

The hydro-electricity generated at the ORDHP Station is governed by water release rules established under a 1994 Water Supply Agreement (WSA) between the Water Authority of WA and Pacific Hydro Pty Ltd. The Agreement enables Pacific Hydro Pty Ltd to release water through the ORDHP Station to generate at least 210 GWhrs/yr of electricity under all but drought conditions. It also provides for the investigation of whether additional water could be made available to generate more than 210 GWhrs/yrs (see Section 6.1.3).

As described in Section 6, provided the 1994 WSA is renegotiated, an average of between 225 and 245 GWhrs/yr can be generated at the existing ORDHP Station, depending on the irrigation allocations made for Stage 2 Supply Area developments. This increased output is still at least 80 GWhrs/yr below the expected regional demand in 20011-12. New generating capacity is required in the region if the shortfall is to be met by cheaper (and cleaner) energy sources than the current diesel plants at Argyle Diamond Mine, Kununurra and Wyndham.

Argyle Diamond Mine has sought expressions from potential power suppliers (including Pacific Hydro Pty Ltd) to meet their growing electricity demands. Options being considered include a small hydro-power station at the Kununurra Diversion Dam with approximately 10 MW capacity, and a new power station associated with an enlarged sugar refinery in Kununurra, using sugarcane waste (ba-gasse) as the feed source. Until additional generating capacity is established, the existing diesel plants in the region will supply the shortfall between the ORDHP Station output and the regional demand.

5.4.3 Commercial tour boat operations

The economic importance of water based activities dependent on the Ord River Project infrastructure and Ord River flows was noted in Section 4.2 and Table 9. Commercial tour boat operators rely on the stable water levels of Lake Kununurra to reach most points of interest on their scenic tours of the Lake. However, to enable their boats to navigate upstream to the Ord River Dam, flow rates of at least 50 m^3/sec, and preferably 60 m^3/sec are required in the Ord River. Commercial tour operators that operate fishing trips from the lower Ord to Cambridge Gulf currently have difficulty navigating shallow sections of lower Ord River downstream of Carlton Crossing, under adverse tidal conditions. Reductions in flows in the lower Ord River will make access to Cambridge Gulf marginally more difficult in the future.

5.4.4 Fish passage

Recreational fishing interests have been promoting ways to improve fish migration along the lower Ord River and upstream to Lake Kununurra for many years. Improved fish migration has strong local support from the local community, traditional owners and the Shire. Fisheries WA, Water Corporation and the Department of Water have supported preliminary investigations on fish passage. In 2005, the Fourth Australian Technical Workshop on Fishways was held in Kununurra, and led to Fisheries WA commissioning specific investigations to gauge the effect of migratory barriers on fish of the Ord River, and to investigate fish passage requirements and solutions.

The flow required for fishways to operate effectively depends critically on their design type. A water lift type is expected to be most appropriate to overcome the 15 m barrier of the Kununurra Diversion Dam. This type of fishway uses little water directly, although sufficient velocities are required near the entrance to attract fish into the lift. Careful design of entry conditions is therefore required. The 45 m^3/sec interim EWP flow rate provides scope to establish the required entry conditions.

As noted above, there is potential to develop a small hydro-power plant at the Kununurra Diversion Dam. If the power station proceeds, it will clearly affect the way water is released through the Kununurra Diversion Dam and consequently the way any fishway lift would be designed. Any fishway proposal will need to recognise the potential for a new hydro-power station at the Kununurra Diversion Dam and, to the extent possible, explore ways to make the two proposals complementary.

5.5 Other possible demands

The most recent study of options to supply Perth from the Kimberley considered sourcing up to 200 GL/yr of water from Lake Kununurra and supplying the water via pipeline to Joseph Bonaparte Gulf and then via ocean-going tanker to Perth (DPC, 2006). Although one of the cheapest options investigated, total costs were a very high $5.0/ kL. The Expert Panel set up to review the options rejected the concept of transporting water such long distances, concluding that "the water would cost much more (at least five times) than if supplied by other available options and offer no other significant advantages to the development of the State".

The study's findings of the high costs for transporting water long distances has re-emphasised that the best use of Ord River water is to meet the local irrigation and hydro-power demands in the East Kimberley, as originally planned under the Ord River Irrigation Project.

5.6 Matching available water to expected demands

The following section sets out the resource management objectives of this plan and how the available water is to be shared between the needs of the riverine environment of the lower Ord and the competing demands of existing irrigation in Stage 1 areas, the expansion of irrigation (Stage 2 developments) and hydro-electric power generation.

6 Establishing the water available

6.1 Management objectives and allocation constraints

6.1.1 Management objectives

The resource management objectives of this plan are to

- protect the riverine environment and social benefits of the lower Ord River as they have evolved since the Ord River Dam was constructed;
- ensure that diversions from the Ord River below Lake Argyle are sustainable in the long term;
- protect existing commitments to irrigation and hydro-power generation while providing for growth in both so that economic benefits from the Ord Irrigation project are increased; and
- promote improved irrigation practices so that risks to the lower Ord environment and continued agricultural production are minimised.

6.1.2 Stage 1 irrigation commitments

In September 2004 the OIC was granted an average annual water entitlement of 335 GL/yr. A further 46 other licences with a combined annual water entitlement of 23 GL/yr have been granted in recent years. The additional licences have been issued to irrigators that pump directly from Lake Kununurra and the Ord River and for customers of the Water Corporation that pump from the M1 Channel.
A key aspect of this allocation plan is to ensure these entitlements are protected.

6.1.3 Existing power generation commitments

The ORDHP Station was constructed under the provisions of the *Ord River Hydro Energy Project Agreement Act 1994.* This Act protects the interest of Pacific Hydro Pty Ltd in constructing and operating the ORDHP Station. The Act refers to the Water Supply Agreement for the ORDHP Station, noted in Section 5.4.1, that specifies the water available to the Company for the generation of electricity. The Water Supply Agreement (WSA) is a contract made between the (then) Water Authority of WA (now the Water Corporation and the Water and Rivers Commission) and Pacific Hydro Pty Ltd. The WSA was signed in 1994, prior to water for the environment becoming an integral part of water allocation planning and licensing.

The WSA enables the company to release water at rates sufficient to generate at least 210 GWhrs/yr while the water level in Lake Argyle is higher than 78 m AHD. The WSA also provides for renegotiation of the water release rules after the first 1015 GWhrs of electricity has been sold to Argyle Diamond Mine (occurred in 2003) and the investigation of revised rules that provide for additional electricity to be generated, above 210 GWhrs/yr.

The hydrologic studies carried out when the WSA was being negotiated indicated that 210 GWhrs/yr could be reliably generated in conjunction with the diversion of up to 1,500 GL/yr of irrigation water. However, while 450 GL/yr of this total was identified for diversion downstream of Lake Kununurra, no explicit provision was made to maintain a downstream flow to protect the riverine environment. The 1,500 GL/yr total was seen as sufficient to adequately water irrigable soils of the potential Stage 2 Supply Area. The generation of 210 GWhrs/yr of hydro-electricity was sufficient to meet the expected town and industrial energy demands of the region. Consequently, as both demands could be met[35], there was no significant competition for water between the uses, and no need to determine a water allocation priority between the two. The 1994 WSA, therefore, enabled hydro-electricity to be generated, irrespective of the need to conserve water in storage for irrigation supply during extended drought periods. There were no constraints on the generation of 210 GWhrs/yr until Lake Argyle levels reached a low 78 m AHD, only 2 m above the level at which irrigation restrictions also become necessary.

Given the increased demand for electricity in the region (see Section 5.4.1), and the need to provide water to protect the lower Ord environment, restrictions on the generation of electricity above 78 m AHD will be required if the objectives of the plan are to be realised. Revised water release rules are required so that the average annual amount of electricity generated can exceed 210 GWhrs/yr, while also providing additional water for Stage 2 irrigation developments

6.2 Reservoir simulations

6.2.1 Approach

Sustainable diversion limits for the Ord River are, by definition, the quantities of water that can be diverted from the river, at specified locations, while still maintaining sufficient flow in the river to meet the EWP regime of Table 11. These are assessed through simulating the response of Lake Argyle and Lake Kununurra to inputs of stream flow and rainfall from the Ord catchment, under different dam and power station operating rules. Operating rules are adjusted between simulation runs to reflect different allocation options and ensure that the EWP regime is maintained under each allocation option.

Three sets of reservoir simulations have been carried out since 2000. Each new set updated the projected demands and incorporated improvements in how irrigation and hydro-power demands were simulated. The results presented in this plan reflect the water and electricity demands presented in Section 5. The key features of the simulations are described in the following section.

[35] The irrigation and hydro-electricity demands were defined as monthly average totals. The water releases necessary to meet the maximum of either demand could be met with a high reliability of supply.

6.2.2 Hydrologic data set

Monthly flows at the Ord River Dam site, estimated to have occurred between 1906-67 and 1991-92, formed the primary hydrologic input for the reservoir simulations. This is the same data set as used to develop the water release rules of the 1994 WSA for the ORDHP Station. This stream flow data set was derived from a combination of recorded stream flow data at the main dam site between 1955-71, reservoir operational records between 1972-92, and estimates of stream flow based on catchment rainfalls prior to 1955. Consequently, the series reflects the hydrologic responses to the meteorological conditions experienced between 1906-07 and 1991-92 and catchment land use conditions from 1955-91.

When the historic 1906-67 to 1991-92 data set is used, the implicit assumption being made is that future inflows to the Ord River Dam have the same statistical properties as the historic sequence. Although this assumption may need to be reviewed as knowledge on climate change improves, the historic sequence provides a consistent data set to enable different allocation options to be evaluated. Stream flow data since 1991-92 have been well above the long term average of the historic data set (to 1991-92). Consequently the results of the current simulations are likely to be conservative, by underestimating the reliability of irrigation allocations and the amount of hydro-electricity that could be generated in the future. A revised inflow sequence is being developed for use in future reservoir simulations that will inform the assessment of new licence applications and the revision of this plan.

6.2.3 Simulation package

The Danish Hydrologic Institute's simulation package called MIKEBASIN™ , was used to simulate the water balance of Lake Argyle and Lake Kununurra, and calculate flows in and diversions from the Ord River between the Ord River Dam and downstream of the Dunham River confluence. Water demands were established for the current and proposed irrigation areas (including five separate sub-demands to account for different distribution and on-farm efficiencies) and power generation at the Ord River Dam. The irrigation demands used are given in Appendix 5. Each water demand could be varied as a function of the water level in the main storage (Lake Argyle). This enabled different water restriction policies related to irrigation and hydro-power demands to be studied.

The output included the simulated reservoir levels and achieved diversions for each demand, and river flow rates at the key node points. While most data were based on a monthly time step, the flood storage and spillway configuration required iterative calculations on a daily time step to correctly simulate the water balance, lake levels and spillway outflows. Note that irrigation diversions downstream of House Roof Hill were not explicitly simulated as these can be met from the 45-40 m^3/sec EWP flow regime as noted previously. Figure 17 presents typical simulation results of the current situation case (Stage 1 allocation 350 GL/yr, hydro-electric demand 210 GL/yr, 50 m^3/sec dry season flow in the lower Ord).

Different allocation strategies were investigated by changing the lake trigger levels and severity of restrictions to apply to each demand (or allocation). Input functions that defined the percentage of each demand to be supplied at a specified Lake Argyle water level[36] were adjusted each run to achieve target reliabilities for different allocations. A trial and error approach was necessary to develop an appropriate restriction policy for each allocation option, while ensuring that water level in Lake Argyle did not fall below the minimum operating level[37].

Irrigation demands were calculated for each month of the simulation for each crop type and irrigation application method. This involved using locally derived data on crop water requirements, recorded rainfall data for the irrigated areas, and estimates of on-farm and distribution losses discussed above. The areas of each crop type were varied between each simulation run to alter the overall water demand. Releases to maintain the downstream EWP were computed within the model, as were the releases required to meet the monthly energy demands.

6.3 Potential irrigation and electricity allocations

6.3.1 Under the existing Water Supply Agreement

Reservoir simulations that maintained the interim EWP, released water in accord with the 1994 WSA and met existing irrigation water entitlements, showed that approximately 400 GL/yr of water was available to supply the M2 Supply Area (see Table 13). This can be supplied in approximately 90 per cent of years (or at an annual reliability of 90 per cent). If a higher reliability of 95 per cent were adopted then approximately 300 GL/yr would be available. For the current situation, where the M2 Supply Area allocation is zero, the average electricity able to be generated was estimated to be 204 GWhrs/yr. The simulations indicated that approximately 197 GWhrs/yr (over 95 per cent) was generated from Pacific Hydro Pty Ltd releases made at rates equivalent to their 210 GWhrs/yr provision in the WSA[38].

As irrigation allocations to the M2 Supply Area increase, additional electricity can be generated from the additional water released to meet downstream irrigation and EWP demands. While a small reduction occurs in the electricity generated from releases made at Pacific Hydro Pty Ltd's discretion, the overall amount of electricity generated increases. For an M2 Supply Area allocation of 400 GL/yr (at 90 per cent reliability), the average annual amount of electricity able to be generated increased to 223.2 GWhrs/yr. On average 189.9 GWhrs/yr (or 85 per cent) was generated at Pacific Hydro Pty Ltd's discretion.

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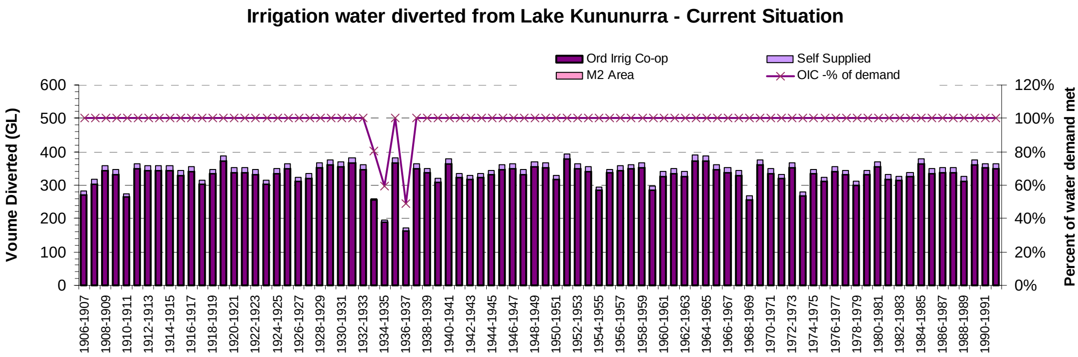
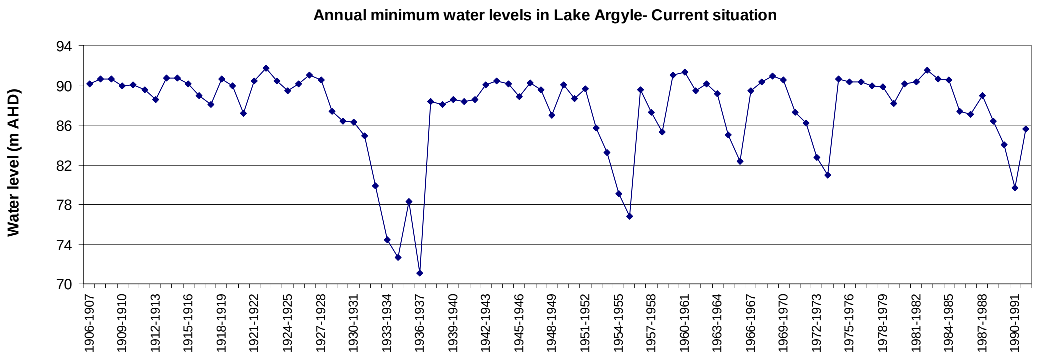
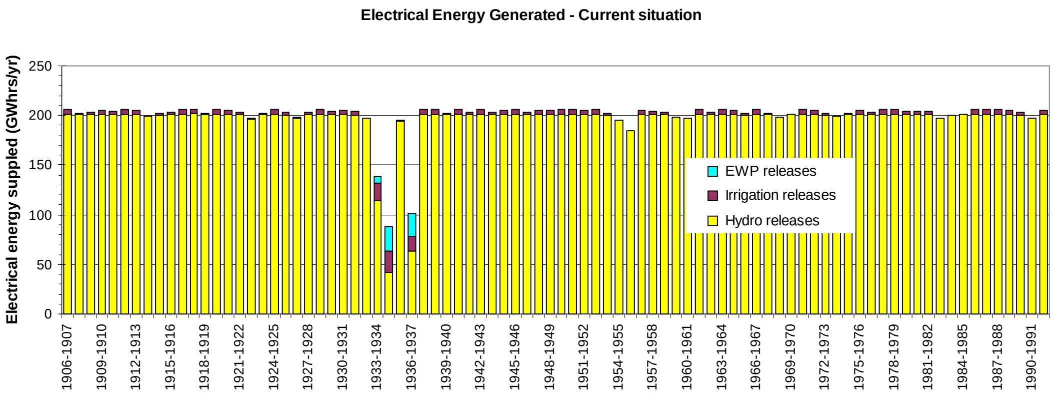
36 The functions could also be defined for each month of the year, enabling restrictions to be applied to different degrees at different times of the year. The approach was used in relation to the hydro-electric power demand.

37 A level of 70 m AHD was adopted as the minimum operating level for this study.

38 The average supplied is less than 210 GWhrs/yr because of the approximately 5 per cent of years water levels are below 78 m AHD







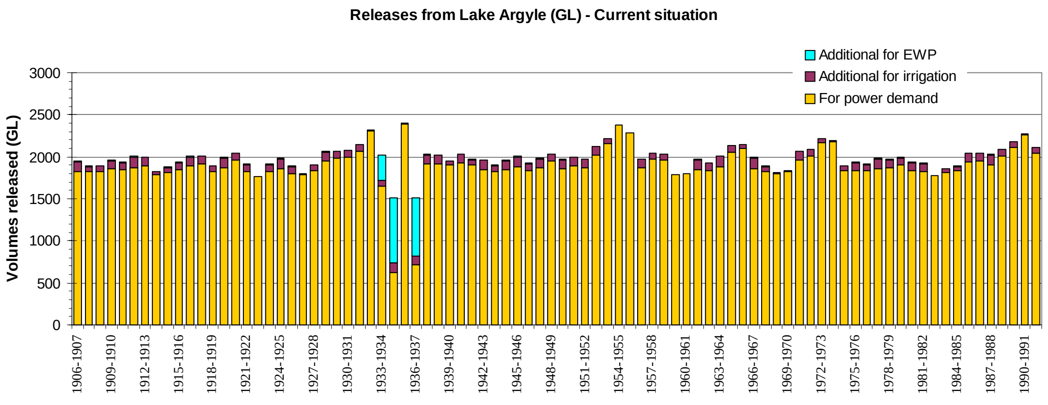


Figure 17 Typical output from reservoir simulations of the current situation case

6.3.2 Under revisions to the 1994 Water Supply Agreement

Limiting flows through the ORDHP Station to rates sufficient to generate only 210 GWhrs/yr, as provided for in the 1994 WSA, unnecessarily constrains electricity production, especially when water levels in Lake Argyle are high (see Table 13). Provided additional constraints are placed on electricity generation when lake levels are low and water for irrigation needs to be conserved, electricity production can be increased significantly when water levels are above average. Overall, the average amount of electricity generated can be increased, above the amounts estimated in Table 13.

Table 13 Allocations achievable under the interim EWP and the 1994 WSA

Irrigation and electricity allocations		**Irrigation reliability (% of Years)**		
		97 %	**95 %** [‡]	**90 %**
Irrigation allocations				
Stage 1 Total	GL/yr	350	350	350
M2 Supply Area	GL/yr	0	300	400
Total	GL/yr	350	650	750
1994 Water Supply Agreement[†]				
Years with lake levels <78 m	Years	4	7	8
Years when WSA was met	Years	77	77	77
Average electricity supplied [§]	GWhrs/yr	204.0	218.4	223.2
Electricity demand component	GWhrs/yr	196.7	191.6	189.9
Generated from other releases	GWhrs/yr	7.3	26.8	33.3

† The 1994 Water Supply Agreement provides for water to be released at rates sufficient to generate 210 GWhrs/yr when levels in Lake Argyle are > 78 m AHD

‡ Estimated from other simulations

§ Does not include extra electricity that could be generated at times of spillage, if sufficient demand was present. This has been estimated to average 16.9 GWhrs/yr under current conditions and 13.3 GWhrs/yr under an M2 Supply Area allocation of 400 GL/yr

Figure 18 shows average electricity production at the ORDHP Station for a range of M2 Supply Area allocations, after new water release rules had been developed that maximised electricity production for each allocation. All simulations used a target demand of 322 GL/yr (equivalent to the projected demand in 2011) and included a Stage 1 demand of 350 GL/yr. The average electricity supplied in all cases exceeded the quantities able to be generated under the conditions of the 1994 WSA (Table 13).

Examples of critical water levels in Lake Argyle below which electricity output had to be severely curtailed, to ensure that the reliability of the irrigation allocation was achieved, are presented Figure 19. As the irrigation allocations increase, the critical water levels need to also increase. As more water is committed to irrigation, additional water must be retained in storage for irrigation use in subsequent years, so that the irrigation allocation and its reliability can be achieved over the simulated 86 years.

Figure 19 indicates that for the higher M2 Supply Area allocations (> 480 GL/yr), water can only be released to meet the full electricity demand when water levels are within a few metres of the base of the spillway. For these allocations most of the electricity generated comes from water released to meet the downstream irrigation and EWP demands, rather than specifically to meet the hydro-power demand.

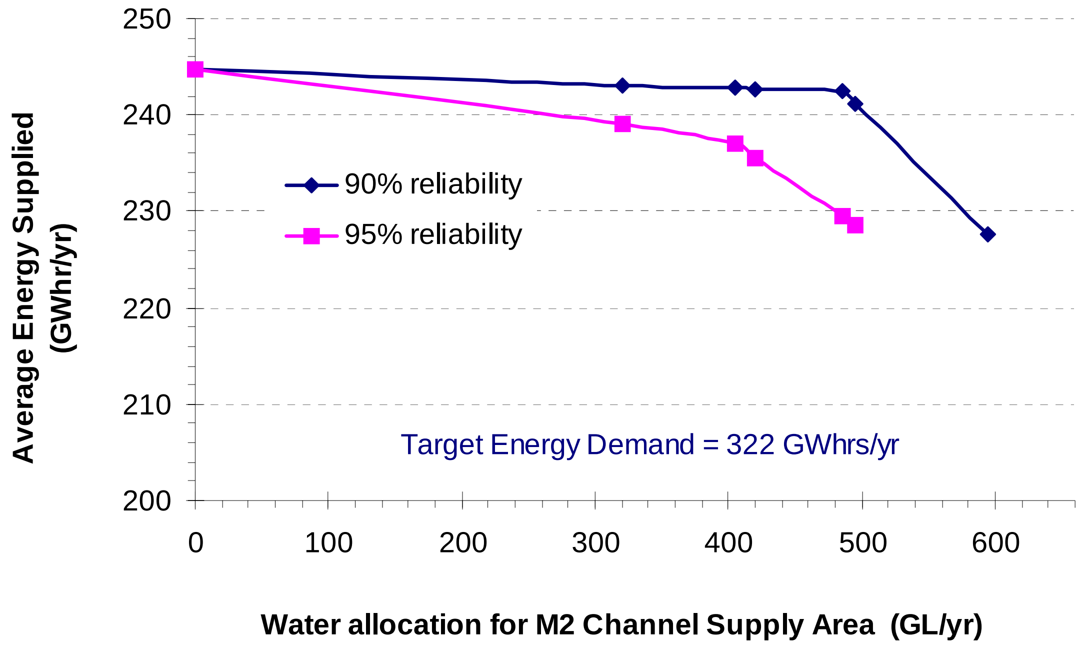


Figure 18 The electricity able to be generated as a function of M2 Supply Area allocations

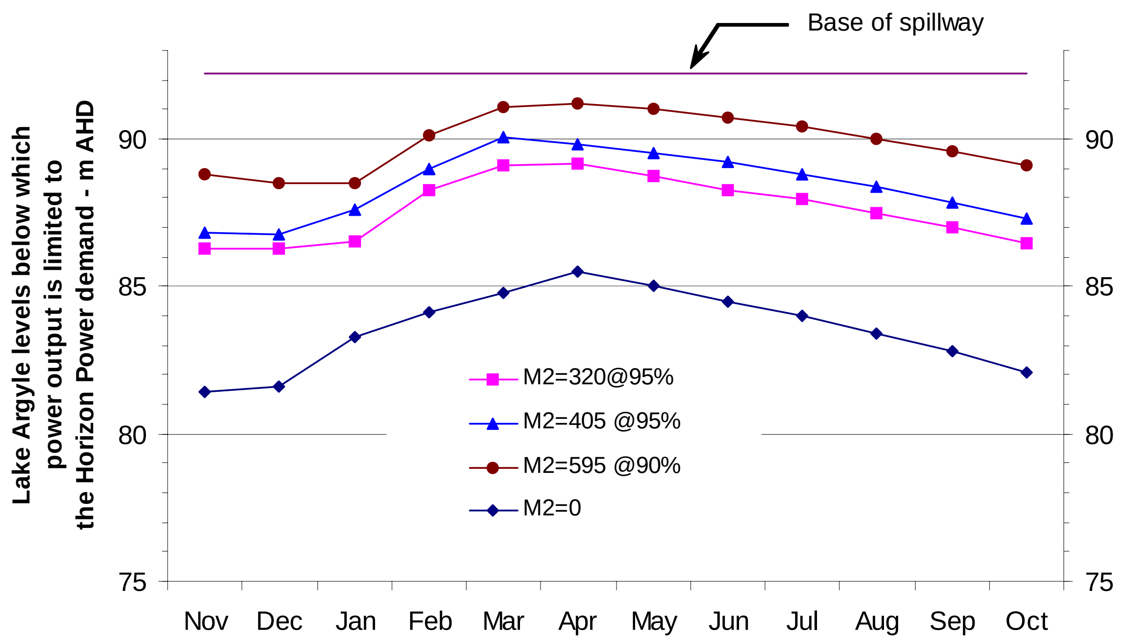


Figure 19 Lake Argyle levels below which power output is limited to Horizon Power demand

Figure 20 shows where the electricity generated from releases made to meet hydro-power demand, and downstream irrigation and EWP demands, is supplied to a range of M2 Supply Area allocations.

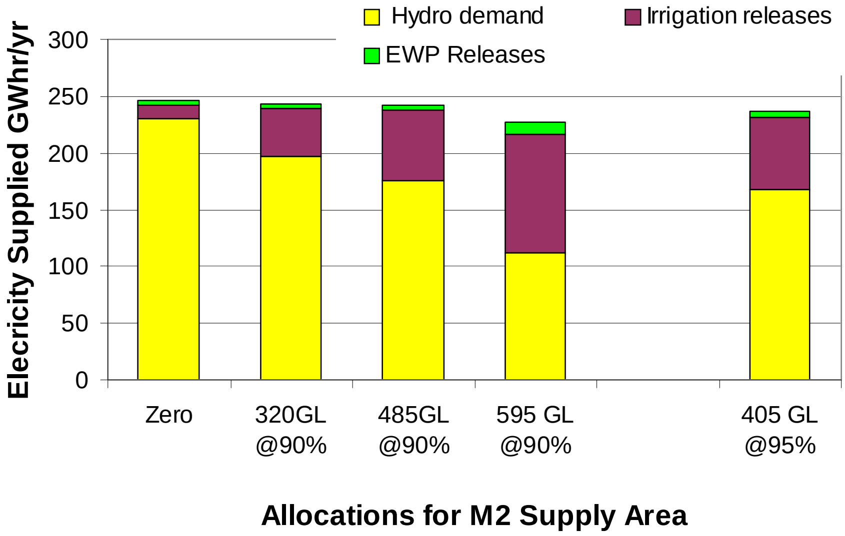


Figure 20 Electricity generated from different types of water

6.3.3 Implications of reservoir simulations for future allocations

Full development of the M2 Supply Area

Given the need to maintain the interim EWP regime and meet the existing Stage 1 entitlements, the reservoir simulations demonstrated that up to 595 GL/yr can be supplied from Lake Kununurra in 90 per cent of years. This allocation is sufficient to irrigate sugarcane over 75 per cent of the full M2 Supply Area (30,000 ha of gross farmland), with the remaining 25 per cent being used to grow a mix of horticultural or other broad acre crops with an irrigation water requirement of about 10-11 ML/ha at the farm gate (about half that of sugarcane).

As shown in Figure 18, the amount of electricity that can be generated for an M2 Supply Area allocation of 595 GL/yr is limited to an average of 228 GL/yr and contrasts with the 245 GWhrs/yr that can be supplied if M2 Supply Area development were not to proceed. This is 18 GWhrs/yr greater than the amount guaranteed under the 1994 WSA, although it represents a 17 GWhrs/yr (or 7 per cent) reduction below the maximum possible if the M2 Supply Area did not proceed. This potential constraint on electricity production is small relative to the regional demand. However, given high fuel costs, the additional cost to generate the 17 GWhrs/yr at the diesel plants of the region is likely to exceed $3 million/yr.

Although the economic benefits likely to be generated from allocating 595 GL/yr to irrigation should be significantly more than $3 million/yr, it is not necessary to determine an economic optimum between full development of the M2 Supply Area and hydro-electricity generation at this stage. Construction of the NT portion of the M2 Supply Area cannot proceed until Native Title and Aboriginal heritage issues are resolved in that jurisdiction. This is not expected to be achieved for several more years.

However, determining how best to balance additional hydro-electricity generation with additional irrigation allocations to supply the full M2 Supply Area will be a central aspect of future revisions of this management plan.

Development of the Western Australian portion of the M2 Supply Area

As discussed in Section 5.3, the maximum irrigation demand for the WA portion of M2 Supply Area is not expected to exceed 360 GL/yr and should certainly not exceed 400 GL/yr. Under an initial allocation of 400 GL/yr (at an annual reliability of 95 per cent) for the M2 Supply Area, an average of about 237 GWhrs/yr could be generated if new (optimal) water release rules are implemented for the power station (Figure 18). This is only 7 GWhrs/yr (or 3 per cent) less than the maximum able to be generated if the development did not proceed.

Development of the WA portion of the M2 Supply Area is expected to generate tens of millions of dollars of increased agricultural production (see Table 9) and more than offset the additional 7 GWhrs/yr from diesel fired plants in the region (approximately $1.0-1.5 million/yr).

Figure 21 shows simulations of Lake Argyle water levels and releases, irrigation diversions from Lake Kununurra and the quantities of hydro-electricity generated when the allocation from Lake Kununurra totals 755 GL/yr (Stage 1 Areas 350 GL/yr, M2 Supply Area 405L/yr) are shown. The simulations were carried out for a hydro-electricity demand of 322 GWhrs/yr, and approximate the demand projected to develop around 2011-12.

Additional hydro-electricity generation potential at the Kununurra Diversion Dam

As part of each reservoir simulation, calculations were made of the flows released through the Kununurra Diversion Dam over the 86 years of the simulation. These releases provide most of the interim EWP for the lower Ord River, especially in the dry season. Calculations were made on the amount of electricity that could potentially be generated from these flows by a small hydro-electric power station at the dam. Approximately 15 m of pressure head is available and a maximum flow rate of 100 m^3/sec was adopted for the station. Calculations were undertaken for the case of no M2 Supply Area development and the case of maximum allocation to the M2 Supply Area (595 GL/yr)[39]. These bracket the likely range of flows expected at the Kununurra Diversion Dam in the future.

39 Both allocation cases incorporated the high regional power demand of 322 GWhrs/yr.

The monthly patterns of the electricity generated are shown in Figure 22 and Figure 23. Under the maximum possible allocation for the M2 Supply Area (595 GL/yr), between 50-55 GWhrs/yr of electricity could be generated at the Kununurra Diversion Dam. If no M2 Supply Area development occurred, the amount could increase to 75-80 GWhrs/yr.

The monthly quantities of electrical energy generated are relatively constant in dry season months and reflect the stable interim EWP flow regime, especially the case of maximum allocation to M2 Supply Area (Figure 22). Larger variations occur in the wet season months and reflect the variable wet season discharge through the Kununurra Diversion Dam caused by natural runoff from the catchment between the dams, and spillage from Lake Argyle in above average years.

A change in the interim EWP regime will directly impact on the amount of electricity able to be generated. While a future lower EWP flow regime will reduce the amount potentially available at the Kununurra Diversion Dam, it will increase the amount able to be generated at the ORDHP Station (for the same irrigation allocation). Overall, a similar total amount of electricity is likely to be potentially available.

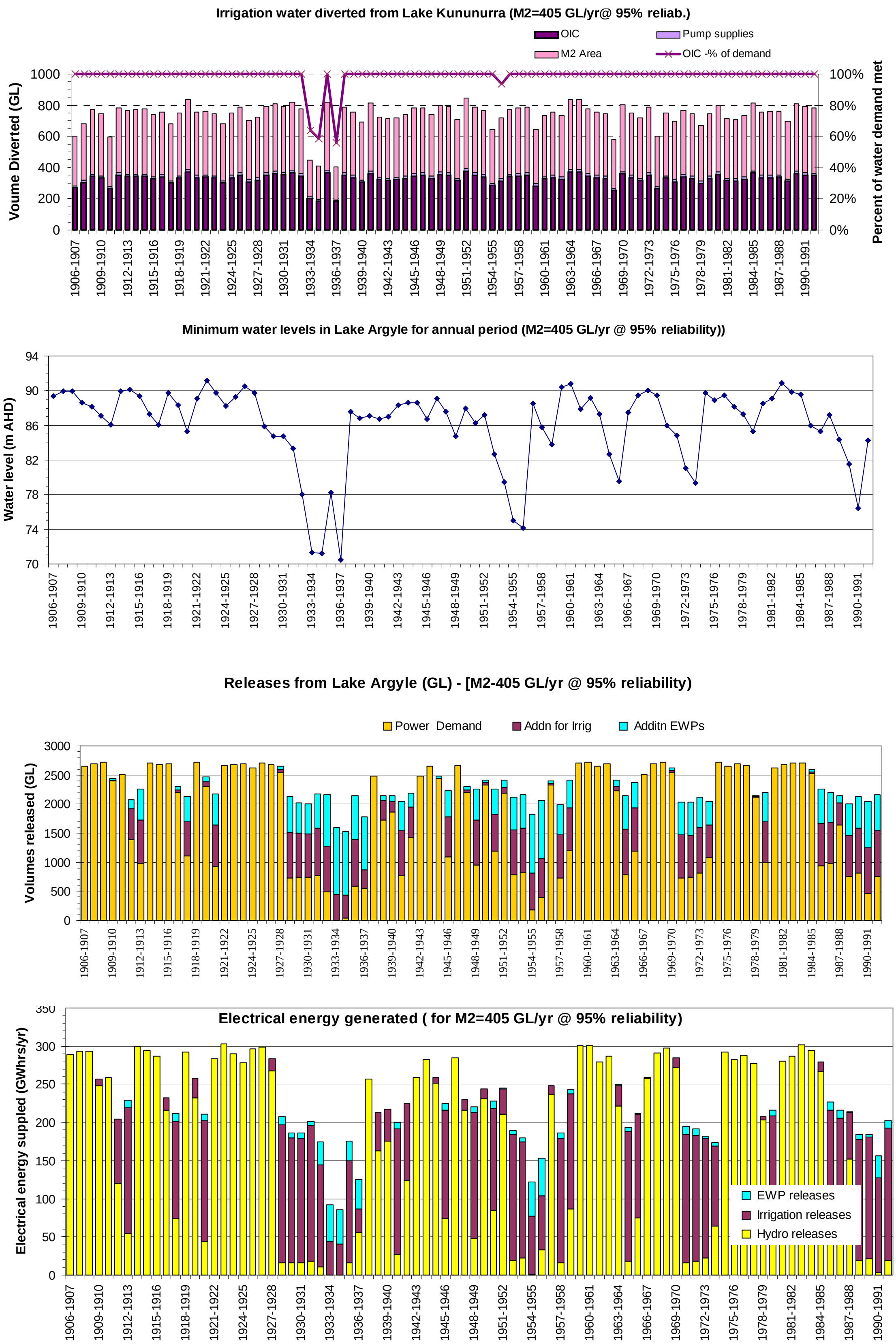


Figure 21 Simulation of a 755 GL/yr irrigation allocation (Stage 1-350 GL/yr, M2-405 GL/yr)

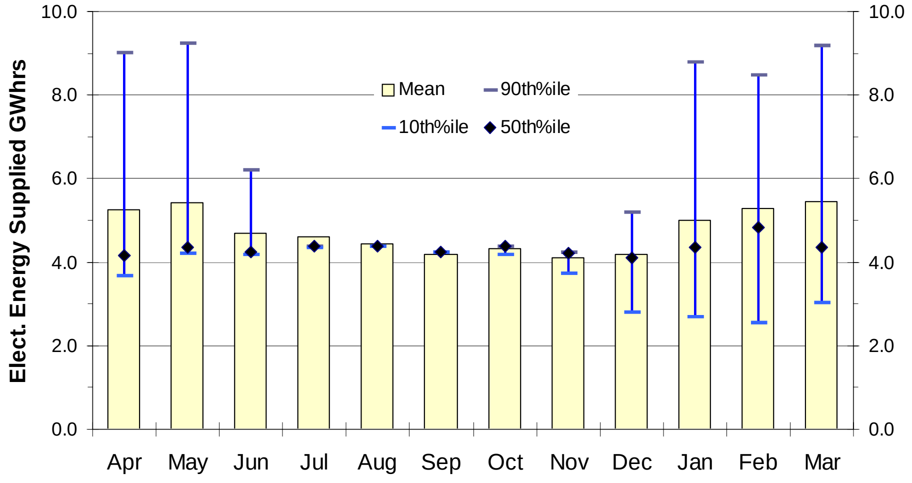


Figure 22 Diversion Dam hydro-electricity potential - under an M2 Supply Area allocation of 595 GL/yr

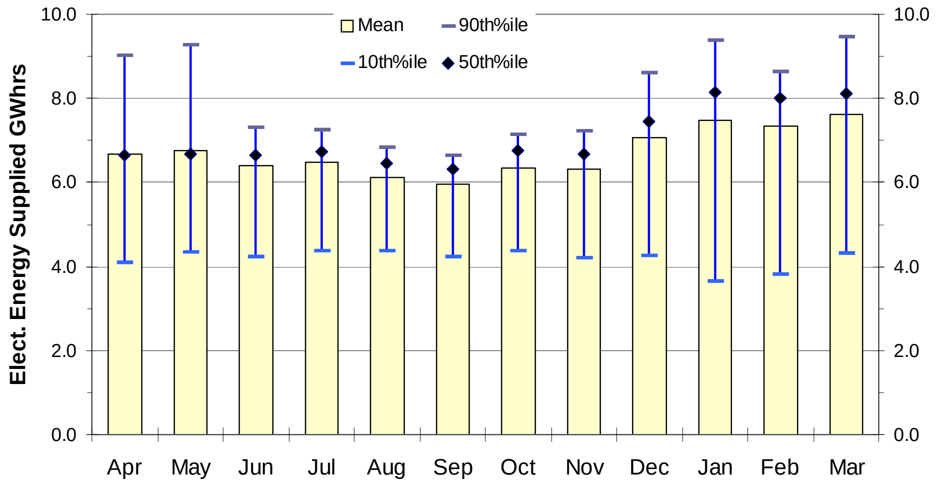


Figure 23 Diversion Dam hydro-electricity potential – with no M2 Supply Area development

7 Water allocations and sustainable diversion limits

Given the demand projections of Section 5 and the simulations described in Section 6, the following water allocation strategy is proposed. The strategy restates the interim flow regime for the lower Ord (Table 11, Section 4.4.2) and specifies the amount and conditions under which water can be made available to meet expected water demands over the next three years. The sustainable diversion limits from the Ord River downstream of the Ord River Dam are summarised in Table 14.

7.1 In-stream allocations

7.1.1 Protection of the riverine environment

Essential in-stream ecological processes and the biodiversity of the lower Ord River, that have characterised the riverine environment since the river has been regulated by the Ord River Dam, are to be protected by the following flow regime:

- When water levels in Lake Argyle are above 76 m AHD (expected 95 per cent of the time) the Ord River is to be maintained at an average monthly flow rate of at least:
  - 45 m^3/sec between the Dunham River confluence and House Roof Hill; and
  - 40 m^3/sec downstream of House Roof Hill
- During drought periods, when water levels are less than 76 m AHD (expected 5 per cent of the time)[40]
  - 35 m^3/sec between the Dunham River confluence and House Roof Hill; and
  - 30 m^3/sec downstream of House Roof Hill
- No significant increase is to be permitted in the regulation of the Dunham River tributary.

The Water Corporation is responsible for maintaining this environmental water provision. This responsibility is established through conditions of their RIWI Act licence that specifies how the Ord River Dam and Kununurra Diversion Dam are to be operated.

7.1.2 Hydro-electric power generation at the Ord River Dam

Water Corporation's Ord River Dam licence also provides for the release of water through Pacific Hydro Pty Ltd's ORDHP Station. Currently, releases are made in accord with the existing water release principles of the 1994 WSA between Pacific Hydro Pty

[40] Restrictions on irrigation diversions and hydro-power generation will also apply during these drought periods.

Ltd and the Water Authority of WA.[41] New release rules have been developed to protect the reliability of Stage 1 allocations while the power station's annual electrical energy load exceeds the current minimum provision of 210 GWhrs/yr, and before new generating capacity is constructed in the region. These changes are being negotiated with the company in accord with the provisions of the *Ord River Hydro Energy Project Agreement Act 1994* and will be implemented through revisions to Water Corporation's licence. Release rules will be updated as additional water entitlements are granted and the M2 Supply Area is developed.

Provided agreement can be reached with Pacific Hydro Pty Ltd to restrict hydro-electricity generation as water levels in Lake Argyle decline, to protect existing and planned irrigation allocations, the Department will support an increase in generation at higher water levels. Overall, an average of at least 225 GWhrs/yr should be able to be generated from the ORDHP Station. Under the sustainable diversion limits of this plan (see below) an average of at least 235 GWhrs/yr should be able to be generated.

7.1.3 Hydro-electric power generation at the Kununurra Diversion Dam

The Department will support proposals to generate hydro-electricity at the Kununurra Diversion Dam. The water available for electricity generation will be restricted to flows released through the dam to meet the downstream EWP flow regime or to discharge surplus inflows to the dam. This run of river provision excludes specific releases being made from either Lake Argyle or Lake Kununurra, for electricity generation at the Kununurra Diversion Dam. Consequently, the electricity able to be generated is directly dependent on the EWP regime for the lower Ord River. Under the interim EWP regime of this plan, an average of at least 50 GWhrs/yr, depending on the design of the station, is potentially available. While additional electricity can be generated while water is not being diverted for the M2 Supply Area, the Department will not guarantee a specified quantity of water for electricity generation at the Kununurra Diversion Dam.

7.1.4 Fishway at the Kununurra Diversion Dam

The Department will provide water to support a fishway at the Kununurra Diversion Dam, provided the required flow is minimised and does not significantly reduce the hydro-electricity potential at the dam. Proposals requiring a continuous flow rate of more than 1 m^3/sec would not be supported.

7.2 Sustainable diversion limits from the Ord River

7.2.1 Lake Kununurra to Tarrara Bar

The sustainable diversion limit for the Ord River between Lake Kununurra and Tarrara Bar is 750 GL/yr. This diversion limit is sufficient to allocate 350 GL/yr for the existing

[41] The Water Authority of WA's functions are now undertaken by the Water Corporation (water service provision) and the Department of Water/ Water and Rivers Commission (water resource management).

Stage 1 demand and to provide for minor growth in Stage 1 demand. The diversion limit is also sufficient to make an initial allocation of 400 GL/yr for future demands in new areas. Future demands are expected to grow in increments, especially as the M2 Supply Area is to be developed in stages, and are not expected to exceed 400 GL/yr for at least three years. Further specifications of these allocations and how water entitlements will be granted are described below:

- The 350 GL/yr allocation for Stage 1 areas has two components. The first 250 GL/yr is based on an expected annual reliability of 95 per cent, and provides for historic use, corrected for expected efficiency gains. The second 100 GL/yr is based on an expected annual reliability of 90 per cent, and provides for demand growth in Stage 1 areas (to October 2006, 46 licences with a total entitlement of approximately 344 GL had been issued).
- The initial 400 GL/yr allocation for future demand is based on an expected annual reliability of 95 per cent. This allocation would be sufficient to irrigate approximately 15,000 ha of sugarcane, given the evapotranspiration and rainfall conditions expected in the M2 Supply Area. Hence the allocation would support the staged development of at least 16,200 ha of gross farmland in the M2 Supply Area (54 per cent of the planned total of 30,064 ha). The allocation would support a larger gross farmland development, if the area committed to growing sugarcane were reduced and replaced by a greater area of other crops with lower crop water requirements[42].

Applications for new water entitlements[43] under this allocation will be required when each new stage of the M2 Supply Area is to proceed or new demand develops. New water entitlements will be granted based on the area to be supplied, and the crop types or type of use planned. The entitlements will be issued with an expected annual reliability of up to 95 per cent, depending on the reliability sought and the crop types or use planned. Efficient water management practices will be expected and will be a condition of granting the new entitlements. In the M2 Supply Area, this means the use of best irrigation practices, including automated control and scheduling systems for water distribution and on-farm water recycling facilitates.

In accord with the provisions of the *Ord River Hydro Energy Project Agreement Act 1994,* Government will consult with Pacific Hydro Pty Ltd when an application for new water entitlements under this allocation is received. Potential new water release rules for the ORDHP Station will be developed to be compatible with the expected water entitlement total, if the application were granted (in whole or part). Final water release rules will be negotiated with Pacific Hydro Pty Ltd with the aim of ensuring sufficient water is available for the staged development of the M2 Supply Area, while protecting the commercial interests of the company. Current studies indicate that, if the initial 400 GL/yr allocation were all granted as entitlements (at 95 per cent reliability), compatible

[42] The full 30,064 ha of farmland in the M2 Supply Area could be developed if sugarcane plantations were limited to ~ 5,500 ha and the remaining irrigable areas used to grow a mix of crops with similar crop water requirements as cotton.

[43] The application, assessment and procedures involved in granting water entitlements are specified in the licensing provisions of the RIWI Act.

water release rules can be developed that would not significantly impact the company's commercial interests. This was found to be the case even when the power demand on the ORDHP Station was assumed to be at or near the maximum output of the station.[44].

7.2.2 Downstream of House Roof Hill

The sustainable diversion limit from the lower Ord River, downstream of House Roof Hill, is 115 GL/yr. This allocation has an expected annual reliability of at least 95 per cent (similar to the EWP reliability) and is planned to supply future developments in the Mantinea Plain and Carton Plain areas. Water entitlements will be granted up to the allocation limit, depending on the application(s) made, the areas to be supplied, and the uses and crop types proposed. The applicant(s) and irrigators will be expected to establish efficient water distribution infrastructure and on-farm watering equipment, and implement best irrigation practices.

7.2.3 Combined sustainable diversion limit - downstream of the Ord River Dam

Table 14 summarises the sustainable diversion limits for the two reaches of the Ord River and includes the estimated annual reliabilities of the various components. The combined sustainable diversion limit from the Ord River, downstream of the Ord River Dam, is 865 GL/yr. All but 100 GL/yr of this total has an estimated annual reliability of 95 % or better.

[44] Reservoir simulations based on maintaining the current environmental water provisions, and supplying irrigation entitlements of 750 GL/yr in 95 per cent of years (Stage 1 and M2 Areas), indicated that an average of over 235 GWhrs/yr of electrical energy could be generated. The monthly demands used were at or near the station's capacity of 37.4 MW in most months of the year.

Table 14 Sustainable diversion limits from the Ord River downstream of Ord River Dam

Reach of the Ord River	**Component**	**Annual average GL/yr**	**Annual Reliability (%)**
Lake Kununurra and the first 30 km downstream of the Kununurra Diversion Dam (to Tarrara Bar)	Stage 1 areas – historic	250	95
	Stage 1 areas – growth	100	90
	Stage 1 areas – combined	350	90+
	M2 Supply Area	400	95
	Total	750	90+
Downstream of House Roof Hill (from ~ 58 km downstream of the Kununurra Diversion Dam)		115	95+
Total		865	90+

8 Implementing the plan - Managing use through water licensing

8.1 Legislative basis for water licensing

The licensing provisions of the RIWI Act provide the legal basis for controlling access to and managing water resource use in WA. It is an offence to take water without a licence from a watercourse proclaimed under the RIWI Act. The RIWI Act provides for water to be taken legally without holding a licence in special circumstances. These include cases where small quantities of water are taken for ordinary and emergency use, or if local by-laws have been written to manage water use by means other than licensing[45].

As defined in the Act, "take" means "*to remove water from, or reduce the flow of water in, a watercourse… including by — "(b) stopping, impeding or diverting the flow of water …. and includes storing water during or ancillary to any of those processes or activities* ". A licence authorises the licensee to take water from a specified water resource, and defines the quantity (water entitlement) and location from which the water may be taken, and conditions under which the water must be taken.

Schedule 1 of the RIWI Act details the Act's licensing provisions and covers the application, granting and revision of licences. Applications are required for new licences and to vary, renew or transfer a licence or water entitlement. In exercising its discretion to grant or refuse an application, the Department is to have regard to all matters it considers relevant including those listed in clause 7(2) of Schedule 1. Matters to which licence terms, conditions or restrictions may relate are included in the appendix to Schedule 1. In cases where the Department considers an application, if granted, may lead to a significant impact on the environment, it is required to refer the proposal relating to the application to the EPA, under provisions of the *Environmental Protection Act 1986*.

8.2 Licensing approach for the Ord River resource

8.2.1 Activities controlled under licence

Managing the flow and controlling diversions from the Ord River and its catchment, down-stream of the Ord River Dam, requires licensing of the following activities:

- the operation of and storage of water behind the Ord River Dam and Kununurra Diversion Dam; and
- the diversions of water from the Ord River and its tributaries[46].

[45] A licence is also not required if the right to take water is granted under another written law.
[46] The Ord River catchment was proclaimed under provisions of the *Rights in Water and Irrigation Act 1914* in 1960.

Licences held by the Water Corporation specify the operation of the Ord River Dam and ORDHP Station and the Kununurra Diversion Dam and control the flow in the Ord River below the Ord River Dam. Licences are also held by the Ord Irrigation Co-operative and irrigators that pump direct from Lake Kununurra or the downstream river.

Applications for new licences or additional water entitlements will be considered favourably, provided that granting of the application will not cause the total water entitlements to exceed the sustainable diversion limits of this plan. Features of current licences and licence conditions, and conditions to be applied to new licences are described in subsequent sections.

8.2.2 Licensing policy

Under current policy, licences to take water from the Ord River have been issued for periods of five years. Under the *Rights in Water and Irrigation Act 1914* there is a presumption that licences will be renewed unless the licence states otherwise, serious impacts or major changes to the resource or its environment have occurred since the licence was issued, or licensees have not been responsible in exercising their water rights (see Clause 22 of the Act)[47].

Government policy is to move to rolling longer term licences of 25 to 40 years, with review every 10 years. These are to be introduced after statutory allocation plans have been completed. It is anticipated that this plan will be replaced by a new statutory plan in approximately three years.

8.3 Managing flows in the Ord River

8.3.1 Current licence and operating strategy for the dams

The Water Corporation hold a licence that regulates their operation of the Ord River Dam and the Kununurra Diversion Dam. These dams take water from the Ord River, in the sense defined in the RIWI Act, by impeding the natural flow of the Ord River and storing water in Lakes Argyle and Kununurra. The Water Corporation operates these dams on a day to day basis in accord with conditions of the licence. These include requirements to:

- release water from Lake Argyle and maintain water levels in Lake Kununurra to meet the needs of irrigators that divert water from Lake Kununurra;
- maintain the interim EWP regime in the lower Ord River;
- enable Pacific Hydro Pty Ltd to release water to generate hydro-electricity in accord with the 1994 WSA;

[47] Examples where renewal of a licence may not be granted include if the renewal is inconsistent with a plan approved under the Act, the licensee has not complied with conditions of the licence, or there are sufficient grounds to cancel the licence under Clause 25.

- implement an operating strategy that details how the dams are to be operated and the interim EWP regime is to be maintained in the lower Ord River;
- monitor and report reservoir operational data including reservoir releases, water balance calculations and the quantities diverted to their bulk customers; and
- report compliance (or non-compliance) with the licence.

While the licence authorises the storage of water and establishes conditions for the release of water from storage, it does not authorise the diversion of water from the Ord River and therefore has a zero water entitlement. Other licences (see below) have been issued to authorise the diversion of water from the Ord River.

The operating strategy for the dams details the way the licence conditions are to be met. The current operating strategy includes:

- procedures for ensuring that the EWP are maintained in the lower Ord River;
- responsibilities for exchanging information with the Ord Irrigation Co-operative and the Department to ensure water diversions are coordinated;
- requirements to maintain water levels in Lake Kununurra within a (narrow) specified range to facilitate diversion and distribution of water throughout Stage 1 areas;
- provisions to estimate water levels in Lake Argyle over the forthcoming months, based on expected irrigation and hydro-electricity demands, to identify the risk that restrictions could be triggered over the next 6 to 18 months; and
- details of lake levels, flow releases and diversions from the Ord River that are to be measured and reported to the Water and Rivers Commission.

Note that the operating strategy for the dams does not explicitly manage water levels in Lakes Argyle or Kununurra to maintain their nominated Ramsar values (see Table 5, Section 2.5). These man-made wetland values are seen as largely compatible with the primary purpose of providing a reliable water supply for irrigation. Land planning instruments (local planning strategies, town planning schemes) and the management of the land flanking the lakes are important in maintaining their ecological, social and other economic values.

8.3.2 Revision of the dams licence and operating strategy

As electricity demands increase and the M2 Supply Area is developed

The water release rules for the ORDHP Station and the diversions from Lake Kununurra need to be revised as electricity demands on the station increase and when development of the M2 Supply Area proceeds. The Water Corporation will need to apply to amend their dams licence and operating strategy to account for these changes.

As new M2 Supply Area licences are issued (see below), revised water release rules for hydro-electricity generation will be established, and associated changes made to the dams licence and operating strategy, to ensure compatibility between all licences dependent on waters released from Lake Argyle.

Providing for hydro-power generation at the Kununurra Diversion Dam

Rights to water for hydro-electricity generation at the Kununurra Diversion Dam will be granted through amendments to Water Corporation's dams licence. When a power station proponent (Pacific Hydro Pty Ltd or other party) has reached agreement with Water Corporation to proceed with a specific development, the Water Corporation will need to apply to amend their dams licence, providing details of the proposal. The application will be considered favourably on the basis that the flows used to generate electricity will be limited to those needed to meet the downstream EWP regime or to discharge surplus water downstream. With the exception of emergency situations, no approval would be given to make releases from Lakes Argyle or Kununurra specifically to generate electricity at the Kununurra Diversion Dam. The approval would also provide for the Department to modify the EWP regime of the lower Ord River in the future.

Providing for a fishway at the Kununurra Diversion Dam

As with a hydro-power proposal, rights to water for a fishway at the Kununurra Diversion Dam would be granted via an amendment to Water Corporation's licence governing the operation of Kununurra Diversion Dam. Following agreement with fishway proponents, Water Corporation would need to apply to amend their licence to authorise additional releases for the fishway. The Department would consider the application favourably provided:

- clear benefits to fish populations could be demonstrated or expected, and adverse impacts unlikely;
- the fishway was designed to minimise the flow requirement (including any flow needed to attract fish to the entry); and
- the flow required did not significantly reduce the hydro-electricity potential of Kununurra Diversion Dam.

Any fishway requiring a continuous flow rate of 1 m^3/sec or more would not be supported.

8.4 Managing Stage 1 (current) water use

8.4.1 The Ord Irrigation Co-operative's licence and operating strategy

The OIC hold a licence for the diversion of an average of 335 GL/yr from Lake Kununurra until August 2009. This annual water entitlement is authorised to be diverted at the M1 Supply Area Offtake and the Packsaddle Pump Station and distributed to the

Cooperative's 62 shareholders. The licence is issued for the purposes of distribution and supply to irrigators for irrigation use, and for non-potable commercial uses, in areas serviced by the Stage 1 channel systems of the District. The annual entitlement includes provision for development of 1,390 ha (gross land area) known as Green location[48].

Based on the hydrologic data set for 1906-07 to 1991-92 period, 240 GL/yr of the licensed entitlement is expected to be supplied in 95 per cent of years and the remaining 95 GL/yr in 90 per cent of years.

For crops that grow throughout the year, such as sugarcane and tree crops, rainfall can significantly contribute to the crops' water demand during the wet season. Depending on the amount of wet season rain, and its distribution through the season, the amount of supplementary irrigation water needed during the wet season can vary greatly from year to year. Consequently, the annual irrigation requirements of sugarcane plantations also vary from year to year, depending on wet season rainfall.

Provision has been made to account for variations in water demand between annual periods by setting an Annual Allocation Limit (AAL). The AAL is set by the Department during April each year. The amount of wet season rain is known at this time and the need to apply any water restrictions during the remainder of the annual period (the dry season) can be reliably assessed. In years when rainfall over the Stage 1 areas has been less than average, the AAL is greater than 335 GL/yr. In years when the rainfall is above average, the AAL is less than 335 GL/yr.

The licence includes conditions relating to the management, monitoring and reporting of water use in the area supplied by the OIC, and these are detailed in the operating strategy attached to the licence (WRC-OIC, 2004). The operating strategy established targets or aims for improved water management and required the preparation of a water use improvement plan designed to meet these targets over the period of the licence (draft prepared in 2005). Implementation of the plan is a condition of the licence.

The key targets are to:

- achieve an 80 per cent distribution efficiency by the last full annual period of the licence (Nov 2007 to Oct 2008) and dry season (2008);
- achieve a 50 per cent reduction in irrigation return flows by the last full dry season (2008);
- record no samples that exceed specified trigger levels for contaminant chemicals in water draining (Stage 1) M1 and Packsaddle Supply Areas;
- stabilise groundwater level rises where there is a risk that groundwater levels will reach to within two metres of the surface by June 2009; and

48 Green location is a Stage 2 development, although it is to be supplied via the (Stage 1) M1 Channel system.

- reduce groundwater levels to 2 m below the surface in areas where water levels are already less than 2 m below the surface, and maintain these levels for the duration of the licence.

Considerable consultative planning and negotiations have occurred at local management levels on the best way improvements are to be introduced or advanced. The Ord Land and Water Plan and the draft water use improvement plan identify the goals, objectives and actions to be implemented. The operating strategy has established 50 commitments that are to be introduced within the term of the licence.

OIC's reporting of their 2004-05 annual period shows progress is being made towards most targets, although further improvements are expected in future years, particularly in relation to water distribution efficiency and reducing irrigation return flows.

8.4.2 Water Corporation's licence for M1 Channel customers

The Ord Sugar Refinery and small land holders adjacent to the first 12.8 km of M1 Supply Area remain customers of the Water Corporation and obtain their water by pumping from the M1 Supply Area. Water Corporation holds a licence to divert water into the M1 Supply Area for these customers. The licence has an annual allocation of 3.9 GL/yr, although the net customer use is only about 2 GL/yr. The M1 Supply Area must be filled and flushed to remove residue and weed growth, accumulated from effluent discharged from the town's sewage treatment ponds when the M1 Supply Area is not being used. This is required before the OIC can recommence supplies to their customers. There can be extended periods (weeks) of no flow in the M1 Supply Area during the wet season when rainfall is sufficient to meet the crop water requirements of OIC members. An allowance of an additional 2 GL/yr has been provided for this purpose on a temporary basis.[49]

8.4.3 Licensing irrigators that pump direct from the Ord River

Approximately 60 land owners adjacent to the Ord River (mainly small land holdings <10 ha), have established their own pumps and pipes to divert water directly from Lake Kununurra or the downstream river[50]. These self supplied users are predominantly small scale irrigators, although some diversions are for public and commercial purposes. To divert water lawfully from the Ord River watercourse, each should hold a RIWI Act licence.

While self supplied demand is minor relative to the total irrigation demand, self supplied use should be responsible, efficient, and managed in a similar way to other users in the District.

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[49] The Department has made the licence non-renewable so that the Water Corporation will find an alternative solution and reapply for a smaller allocation. The DEC is also reviewing the licence, issued under the regulations for Part V of the EPA Act that authorises the discharge from the sewage treatment plant to the M1 Supply Area.

[50] Irrigators that divert water from the lower Ord River are located within 15 km of the Kununurra Diversion Dam.

Licensing process

The Department commenced the process of licensing self supply users in 2002, and carried out water use surveys in March 2003 to determine crop areas, crop types and likely irrigation requirements on each of the properties. It advertised the intention to issue RIWI Act licences to all existing self suppliers in April 2004 and has required new applicants since that date to advertise their own application in accord with RIWI Act Regulations.

The annual water entitlements of individual licences have been based on the areas of crops present when surveyed and crop water requirement figures provided by the Department of Agriculture. In addition, all self supply licensees have been expected to adopt irrigation methods that minimise the volume of surface water drainage and improve water use efficiency. In cases of new surface drainage proposals, the Department seeks input from the applicant, and advice from Agriculture WA and other relevant stakeholders. Where necessary, the Department will define specific drainage requirements as conditions of the licence.

To October 2006, 44 self supply licences had been issued with a combined entitlement of 5.1 GL/yr. A further 3 GL/yr is likely to be approved in the near future.

Licence features

The smaller self supplied irrigators have been issued with licences that:

- provide for an average volume of water that may be diverted;
- require efficient irrigation systems to ensure that water is not wasted;
- allow the Department officers access to the property in an agreed manner, for the purpose of inspections; and
- state that the Department may reduce the amount of water that may be drawn, in the event of a drought or other unforeseen circumstances.

In addition to the above, large self supplied irrigators are expected to complete and implement an approved operating strategy, and submit a simple annual report form on water use. In most situations, the operating strategy will be in a simple standard form, prepared by Department. However, if management is complex and use of water has the potential to impact on the environment, a more detailed operating strategy will be required that commits the licensee to management actions to minimise the impact. The annual report form is to be submitted by 31 March every year, and is to document water use in the previous water year (1 November to the 31 October). Based on these annual reports, the Department may require the licensee to submit an application to amend their licensed entitlement.

Metering water use becomes increasingly important as licensed entitlements approach full allocation. A program to meter the larger self supply users is expected to commence by the time the M2 Supply Area is licensed[51]. All self supplied licences have been issued for periods of five years and most are due to expire on 31 March 2009. Prior to the expiry date, a compliance survey will be undertaken at each property to ensure that all licence details are correct and determine whether the licence needs to be amended. It will also enable the Department to update data on self supply use and incorporate it into overall water use in the Ord River Irrigation District.

8.5 Managing water use in M2 Supply Area

8.5.1 M2 Supply Area licence

Before diversions can commence, a new licence must be issued to the irrigation service provider for the new M2 Supply Area. However, the new developer(s), or their nominated irrigation service provider, will be required to apply for the licence in accord with the provisions of the RIWI Act and prepare a supporting operating strategy, describing how water is to be managed in the M2 Supply Area. This can be done when the proponent has determined the crops to be grown, the area to be developed and the water infrastructure required. Under the allocations of this plan, the Department would be prepared to grant a licence with a water entitlement of up to 400 GL/yr at a 95 per cent annual reliability.

The licence will authorise the diversion of water at the point where water is to be diverted from Lake Kununurra for distribution to the M2 Supply Area. Development of the whole 30,060 ha of the M2 Supply Area requires the construction of a new M2 Channel and Offtake from Lake Kununurra, adjacent to the existing M1 Channel and Offtake. However, under an initial 7,000 ha or 16,000 ha development, the diversion point could be the existing M1 Offtake. As spare capacity exists in the first sections of the M1 Channel, construction of the full length of the M2 Supply Area could be delayed to a later time. The licence will be issued when the M2 Supply Area project is given final environmental approval.[52]

The licence and associated operating strategy will include specification of an AAL in April each year, in a similar way to the AAL described for the OIC's current licence. The entitlement will be granted with an annual reliability of at least 90 per cent. Based on reservoir simulations using the current hydrologic period (1906-07 to 1991-92), a 90 per cent annual reliability implies that restrictions (below the AAL) would be required if water levels in Lake Argyle were expected to fall below 79.5 m AHD in the forthcoming nine months (April to December). For an entitlement with a 95 per cent annual reliability, restrictions would be necessary when lake levels were predicted to fall below the lower level of 76 m AHD. Final trigger levels for restrictions will be calculated before the licence is issued, and will depend on updated reservoir simulations that incorporate additional hydrologic data observed since 1991-92.

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[51] Introduction of additional metering of self supply use is a key element of the Government's water reforms, developed in response to the Irrigation Review Final Report, tabled in Parliament on 1 September 2005.

[52] When all pre-operational environmental management conditions and commitments have been met.

Any new project proponent for the M2 Supply Area will be required to implement an efficient modern system of irrigation distribution and on-farm application similar to the commitments made by the M2 Sugar Project proponents in their January 2000 ERMP.

Active water management to achieve zero dry season tailwater return and minimise groundwater accessions will be required, as will a commitment to manage any long term groundwater accumulation to avoid any significant water resource or associated environmental impact. These will become conditions of the new water licence.

In general terms these are to cover the following:

- the construction and operation of an automated channel distribution system (including balancing storage) and water ordering system designed to achieve at least a 85 per cent distribution efficiency;
- the monitoring of the quantities of water diverted from the Ord River, and the total water turned out from the distribution system onto farms;
- implementation of irrigation scheduling using soil moisture measurement, and the operation of tailwater return systems to avoid dry season tailwater discharge;
- monitoring of groundwater systems recharged by irrigation activities, and associated environmental variables, such as riparian vegetation and watercourses in buffer areas, that may become affected by groundwaters in the longer term;
- the commencement of final investigations and construction of the groundwater recovery well system and discharge pipelines when directed by the Commission[53];
- the establishment of contractual relationships with their irrigator customers that specify the irrigator’s water entitlement and which requires irrigators to implement agreed on-farm actions that are, or are to become, part of the licence conditions;
- to restrict or stop the supply of water to any irrigator who is not complying with their contractual commitments that may cause the licensee to breach their licence conditions;
- yearly and three year reporting requirements as specified in the associated operating strategy; and
- the reporting of any unforseen impacts on the water resource, environment or other users of the water resource or related groundwater system.

The way water use is shared between individual properties within the M2 Supply Area will be the responsibility of the licensee. However, the Department will require the licensee to development contracts with their customers that specify (farm gate) water entitlements that, in aggregate, do not exceed 85 per cent (the expected distribution efficiency) of the annual water entitlement on the licence.

[53] The commencement time would be based on two years before groundwater levels are predicted to reach depths in the range of three to five metres below the soil surface

In addition to the water licence, the Department will provide input to the new M2 Supply Area developers' reports on environmental management, buffer management and final engineering layout and design of their revised M2 Supply Area Project. Completion of these (or similar) reports is expected to remain a Ministerial condition of final environmental approval for the revised project. The design of the irrigation blocks and channel and drainage systems and the capacity of the on-farm return systems are particularly relevant as these can significantly affect groundwater recharge and the ability to achieve the expected on-farm efficiencies of 80 per cent.

The service provider for the M2 Supply Area will also require a licence issued under the powers of the *Water Services Licensing Act 1995* by the Economic Regulation Authority. This licence establishes obligations on the service provider to maintain the water distribution assets, operate in a financially responsible way, and provide a defined standard of service to customers. The OIC hold such a licence for their M1 and Packsaddle Supply Areas.

9 The effects of additional allocations

The effects of the allocations of this plan for the ecology of the lower Ord River have been discussed in Sections 3 and 4, and Appendix 3. This section describes the flow regimes expected, likely nutrient concentrations of the flow, and the effects on river ecology, Ramsar wetlands, and Cambridge Gulf (the receiving water body).

9.1 Changes to the flow regime of the lower Ord River

The effects of regulation by the Ord River Dam and water use to 2004-05 on the flow regime of the lower Ord River were described in Section 2. Comparisons were based on flows just downstream of the confluence with the Dunham River over the period 1974-75 to 2004-05 (Table 3). To identify the effect of the new allocations of this plan from the effect of current allocations on lower Ord River flows, results were used from simulations of reservoir operations under the three allocation cases defined in Table 15. The simulations were carried out over the historic inflow sequence of 86 years (1906-07 to 1991-92).

Table 15 Definition of irrigation allocations and electricity demands simulated

Allocation Case	Annual Irrigation Allocations							Annual Electricity Demand		
	Stage 1				Stage 2		Total	Horizon	ADM	Total
	Historic use		Growth		M2 Supply Area					
	GL	Rel.†	GL	Rel.	GL	Rel.	GL	GWhrs	GWhrs	GWhrs
Current situation	250	95 %	100	90 %	0	-	350	55	155	210
High power, no WA M2 Supply Area	250	95 %	100	90 %	0	-	350	79	233	322
High power, with WA M2 Supply Area	250	95 %	100	95 %	405	95 %	755	79	233	322

† Annual reliability of allocation

In the current situation case, the simulation approximated current Stage 1 irrigation allocations, used the hydro-electricity demand of the 1994 WSA (210 GWhrs/yr) and maintained a dry season flow of 50 m^3/sec (the median dry season flow rate since regulation as estimated in 2000) in the lower Ord River. In the high power, no WA M2 Supply Area case, the simulation maintained the interim EWP regime of Table 11, the same Stage 1 allocations and determined the amount of the high 322 GWhrs/yr hydro-power demand that could be met under these conditions. In the case of high power, with WA M2 Supply Area, the simulation maintained the same interim EWP and Stage 1 allocation, but also included the diversion of an additional 405 GL/yr (at 95 per cent reliability) for the WA portion of the M2 Supply Area. Again, the simulation determined the amount of the high 322 GWhrs/yr hydro-power demand that could be met, while achieving the other allocations[54]. The high power, with WA M2 Supply Area case is within ± 10 GL/yr of the component sustainable diversion limits of Table 14, and considered sufficiently close to approximate the expected lower Ord River flows under the provisions of this plan.

9.1.1 Changes in annual and seasonal flows in the lower Ord River

Table 16 summaries the changes in flows in the lower Ord River just downstream of the confluence with the Dunham River for the three allocation cases of Table 15. Unregulated flows for the same period have also been included for comparison.

Table 16 Changes in lower Ord River flows (downstream of Dunham River)

Allocation cases †	**Mean annual flow GL**	**Wet season flow GL**	**Dry season flow GL**	**5 month min. dry season flow rate m^3/sec**
Current situation	3,630	2,210	1,420	52.2
High power, no WA M2 Supply Area	3,250	1,770	1,480	65.4
High power, with WA M2 Supply Area	2,790	1,590	1,210	48.9
Pre-regulation	4,420	4,170	250	1.8
	As % of flows for the current situation			
Current situation	100	100	100	100
High power, no WA M2 Supply Area	89	80	104	125
High power, with WA M2 Supply Area	77	72	85	94
Pre-regulation	122	189	18	3

† See Table 15 for definition of cases.

Table 16 shows the reduction in wet season flows and increase in dry season flows as a result of allowing additional hydro-electricity generation above the current 210 GWhrs/yr (high power, no WA M2 Supply Area case compared with current situation case). As expected, the additional diversion of the 405 GL/yr to the M2 Supply Area in WA reduces wet season and dry season flows (high power, no WA M2 Supply Area case compared with the high power, with WA M2 Supply Area). Reductions in wet season flows due to increased hydro-electricity generation are greater than the reductions due to the additional irrigation allocation.

Changes in the seasonal pattern of flows are presented in Figure 24. The changes in seasonal flows caused by increased hydro-electricity generation are larger than the changes caused by the additional allocation of 405 GL/yr for the WA M2 Supply Area.

[54] As noted previously, the hydro-power demand of 322 GWhrs/yr is expected to develop during 2011-12.

The higher hydro-power releases from the ORDHP Station reducing the amount and frequency of spillage from Lake Argyle over the 86 years of simulation, significantly reduce the average flows between January and April. For most of the dry season (June to October) flows increase with the increase in hydro-electricity generation, and reduce to levels about 10 per cent lower than the current situation case, when the additional 405 GL/yr is diverted from Lake Kununurra. The difference in dry season flows reflects the change from the nominal 50 m^3/sec of the current situation case, to the interim EWP of 45 m^3/sec (and 35 m^3/sec in 5 per cent of years). The change in seasonal flows caused by the initial regulation of the Ord River by the Ord River Dam (pre-regulation case compared with the current situation case) is significantly greater than the changes proposed in this plan (Figure 24 and Section 2).

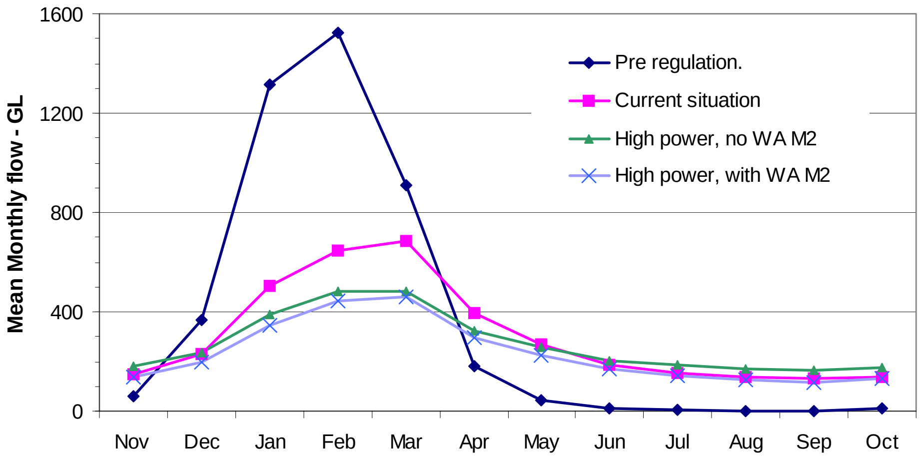


Figure 24 Average monthly flows in the Ord River (downstream of the Dunham River)

The distribution of the 86 dry season flow rates simulated under the three allocation cases are shown in Figure 25. The distributions highlight differences in dry season flows between the high power, no WA M2 Supply Area and with WA M2 Supply Area cases.

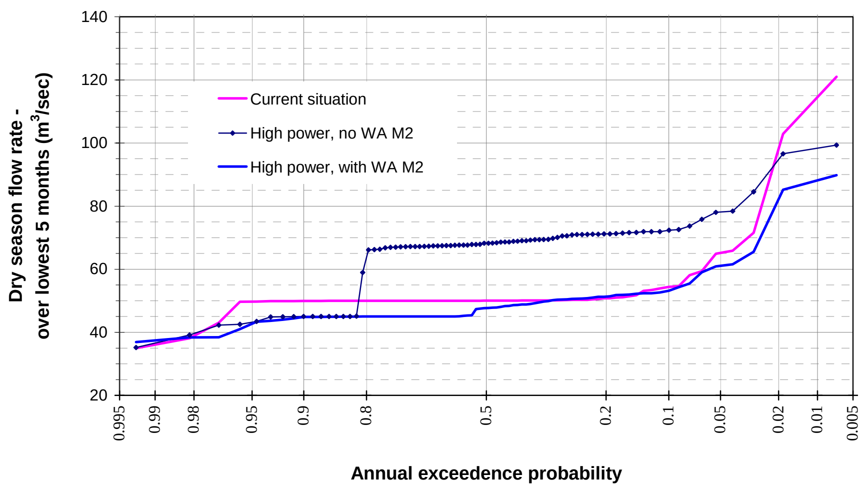


Figure 25 Distribution of dry season flow rates under three allocations

Dry season flow rates of 65 to 75 m^3/sec are common under high electricity demands and no further irrigation diversions from Lake Argyle (as has been occurring in recent years). In 20 per cent of years, however, when reservoir levels are low, the flow in the lower Ord River reflects the interim EWP. At these times, releases through the ORDHP Station are restricted to the Stage 1 irrigation demand and the downstream EWP regime.

9.1.2 Peak flows

Although the wet season volumes will reduce, the annual instantaneous peak flows are only marginally affected by the additional proposed diversions. The flood frequency distributions for the lower Ord River are shown in Figure 26 under current and proposed allocation situations. Also shown are flood frequencies for the Ord River at the Kununurra Diversion Dam and the Dunham River. The downstream peak flow is a combination of flows from the Dunham catchment and the catchment of the Kununurra Diversion Dam. However, the downstream peak is not simply the sum of the peaks from each catchment, as the peaks rarely occur concurrently. Runoff routing calculations and observations of particular floods were used to estimate that the combined peak downstream of the confluence was typically about 87 per cent of the sum of the separate peaks from the Kununurra Diversion Dam and Dunham River catchments. Using this approximation, two distributions of annual peak flows for the lower Ord were estimated together with two estimates of the annual peak distributions for the Kununurra Diversion Dam catchment. These were, in turn, estimated from the maximum monthly releases from the Kununurra Diversion Dam each year as calculated in reservoir simulation runs of the current situation and proposed allocation of this plan.

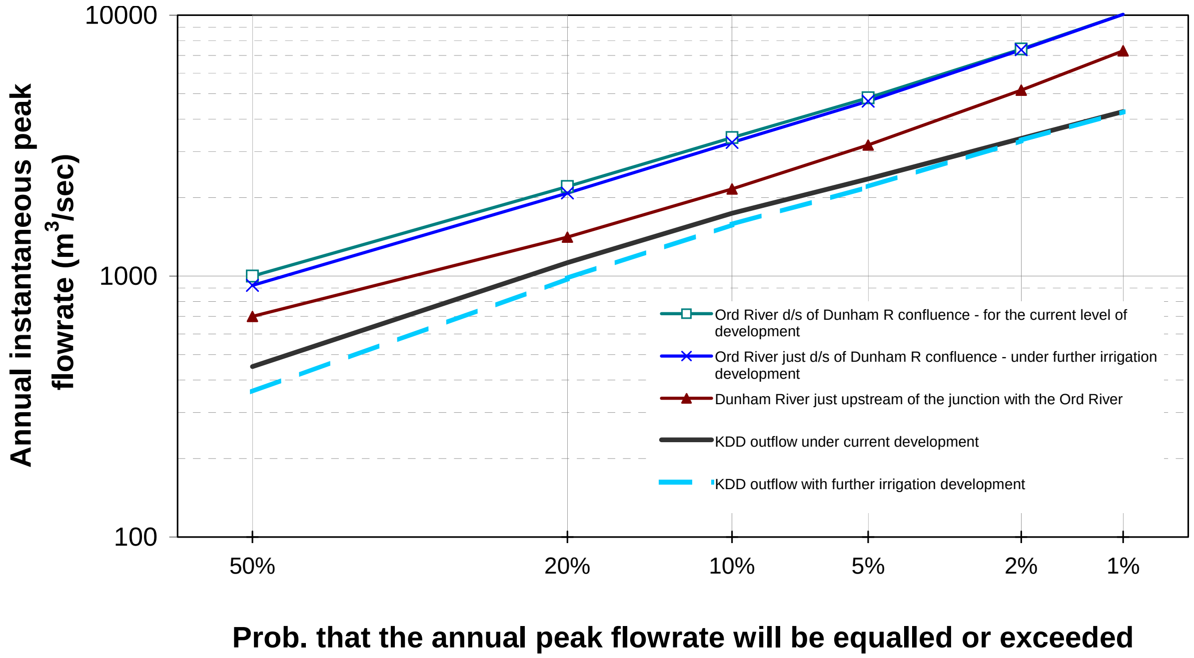


Figure 26 Annual flood frequency distributions under current and proposed allocations

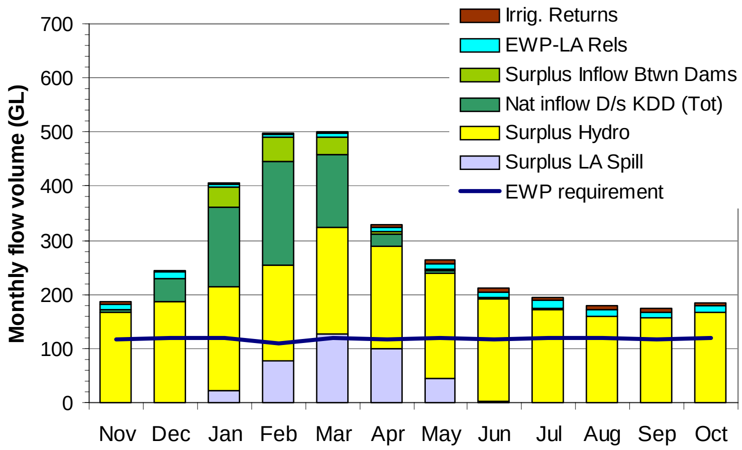
At the bank-full conditions of 4,000 m^3/sec, annual exceedence probability (from the current situation to proposed allocations) changes from 7.3 per cent (roughly 1 in 14) to 6.8 per cent (1 in 15; Figure 26). This small difference in the ecologically significant flood peaks (greater than 50 per cent probability of occurrence) reflects the fact that the post-regulation flood peaks are generated from the predominantly unregulated catchment downstream of the Ord River Dam, and principally from the Dunham River catchment. As indicated in Section 2, the original construction of the Ord River Dam has had a much larger impact on flood peaks of the lower Ord River than will result from the further allocations of this plan (compare Figure 8 with Figure 26).

9.1.3 Contributions to Lower Ord River flows

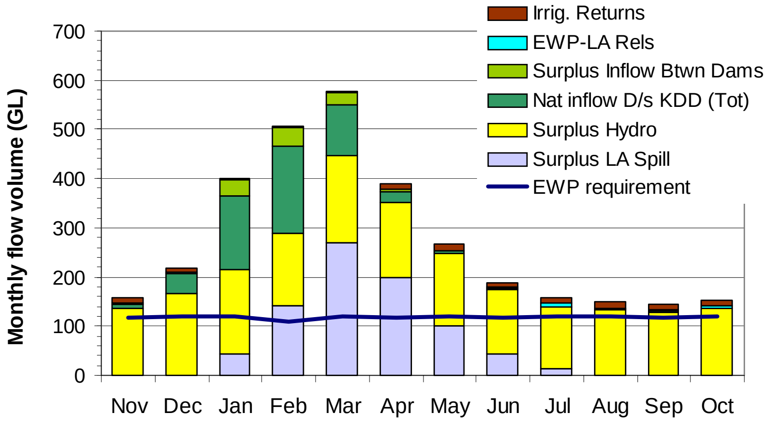
Figure 27 compares the contributions to average monthly flows in the lower Ord River at Tarrara Bar for the current situation, high power no WA M2 Supply Area and high power with WA M2 Supply Area cases. The effect of the high electricity demand on reducing the contributions from spillage from Lake Argyle is apparent from comparing Figure 27 (b) and (c) with Figure 27 (a). Surplus hydro-electricity releases dominated dry season flows in the lower Ord, especially in the high power no WA M2 Supply Area case, and averaged more than the interim EWP (Figure 27 (b)) from June to October. With the additional 405 GL/yr diversion to supply the M2 Supply Area in the high power with WA M2 Supply Area case, specific releases were necessary to supplement the surplus hydro-electricity releases to maintain the interim EWP during the dry season (Figure 27 (c)).

9.2 Nutrient concentrations in the lower Ord River

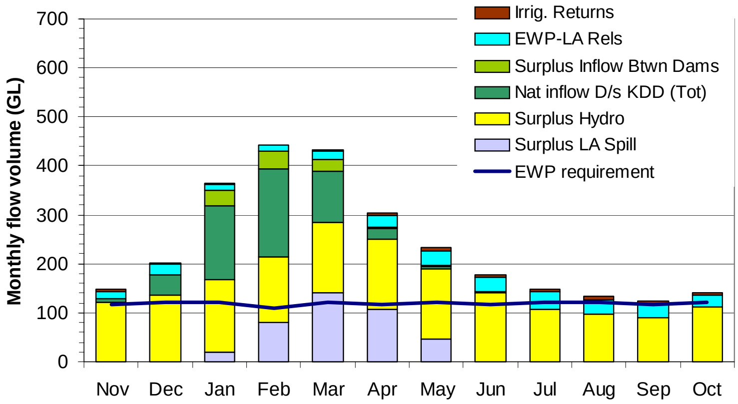
The interim EWP for the lower Ord River limits the reduction in dry season flows to about 90 per cent of historic dry season flows. By maintaining a high dry season flow, the irrigation return flows from Stage 1 areas will continue to be diluted significantly by the flows released through the ORDHP Station and Kununurra Diversion Dam. To complement this means of minimising the risk to water quality in the lower Ord River, the Department has been working with Stage 1 irrigators and the community to promote improved irrigation practices so that the amount of irrigation return flow, nutrient export and risk of contamination events from pesticides in the lower Ord River is reduced (see Section 8.4). Estimates of the effect of improved irrigation management and reduced drainage returns on downstream nutrient water quality are discussed below. Other water quality impacts have been discussed in Sections 3 and 4, and Appendix 3, when describing the interim EWR and EWP regimes.



(a) Current situation



(b) High power, no WA M2 Supply Area case



(c) High power, with WA M2 Supply Area case

Figure 27 Average contributions to Ord River flows at Tarrara Bar

Concentrations of Total Phosphorus (TP) and Filterable Reactive Phosphorus (FRP) were estimated for conditions that represented current irrigation demands and practice, and the proposed allocations with and without reductions in Stage 1 return flows. Calculations were carried out for median flow conditions and for drought conditions. The simulated water year October 1931 to September 1932 was selected to represent drought conditions- flows were less than 20 per cent of median values between October 1931 and April 32. By April 1932 Stage 1 irrigation supplies were reduced to 43.7 per cent of allocation and downstream releases restricted below 45 m3/sec in May and remained at 35 m3/sec to December 1932 (Figure 28). The OIC's licence conditions require implementation of measures designed to reduce current return flows by 50 per cent within 5 years.

The estimates were based on a simple model of monthly nutrient loads of the lower Ord River downstream of all drainage return flows. The nutrient model consisted of three components. These were the nutrient load from the Ord River as it leaves the Kununurra Diversion Dam, the drainage return loads from the Stage 1 irrigation areas and the load from the Dunham River and other small tributaries unaffected by irrigation. The relative water contribution from each component was available from the reservoir simulations. The volume of return flow from Stage 1 areas was a model input. The drainage return flow under current practice was based on recent monitoring of flows in drains[55] discharging from Stage 1 areas. Typical nutrient concentrations were estimated from sample results of Ord River water from Lake Kununurra, drainage return flows from the Stage 1 areas and samples from other tributary inflows unaffected by irrigation or regulation. Monthly averages were determined for each component by pooling sample results from similar sites within the same month.[56].

Similar models of nutrient fluxes that contribute to the lower Ord River have been developed (Lund & McCrea, 2003) using the same data set. The approach used here was designed to directly apply the modelled flow components from the reservoir simulations so that the effect of different operating strategies and water licensing assumptions on downstream nutrient concentrations could be estimated.

Under median water year conditions, the modelled estimates suggest that wet season TP concentrations (Figure 28 (a)) would be higher under the proposed allocations in comparison to current practice. Most of this difference can be attributed to reduced wet season releases from Lake Argyle. The effect of the reduction in minimum flows from 50-45 m^3/sec, even during the dry season, is small. In contrast, reducing the nutrient load from irrigation drainage by 50 per cent has a much larger effect on TP concentrations. Overall TP concentrations are lower during the dry season under the proposed allocations and OIC's licence conditions than under current operational practice. Not surprisingly, reduced drainage flow from irrigated areas has little effect on TP concentrations during the wet season. The wet season contribution of surplus irrigation water is generally small (estimated to be less than 10 per cent of the total wet

[55] 1998-99 was the most complete year with good records of drainage flows.
[56] Results used were based on water samples collected between October 1998 and June 2000.

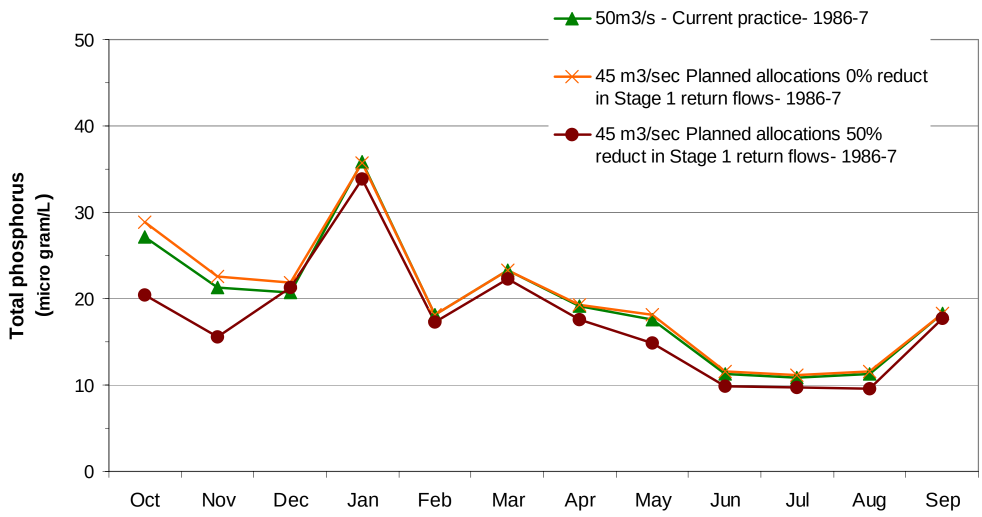
season TP load [57] of the lower Ord River under current conditions). Even if this estimate is reduced by 50 per cent, it will not affect wet season concentrations greatly. However, runoff from heavy rain over the District during the wet can cause significant local erosion and carry significant nutrient loads to the lower Ord River. Implementation of best management practices such as the planting of wet season cover crops can significantly reduce the nutrient export. While included in the model's nutrient accounting, the effects of improved wet season management on reducing this nutrient source were not addressed in this modelling.

Monthly FRP concentrations are generally low, all being below 20 µg/L and all but October and November being below 10 µg/L. However, the National Water Quality Guidelines (ANZECC and ARMCANZ, 2000) suggest that concentrations in excess of 4 µg/L FRP can indicate potential environmental problems in tropical lowland rivers. The FRP level of 4 µg/L is based on a small sub-set of tropical rivers which are not necessarily representative of regulated systems. Under the current flow conditions in the lower Ord River, FRP concentrations are regularly higher than 4 µg/L and prolific phytoplankton or macrophytic growth that would be typical of trophic rivers are not observed. This is likely to be related to the high flow rates, sediment and depth characteristics of the lower Ord riverine environment. Nevertheless, the fact that concentrations above 10 µg/L FRP occur in the lower Ord River indicates that nutrients are available to stimulate biological activity if the right conditions are allowed to develop. The interim EWP (45-40 m^3/sec) maintains most of the current high base flow and limits the chance of eutrophic conditions developing.

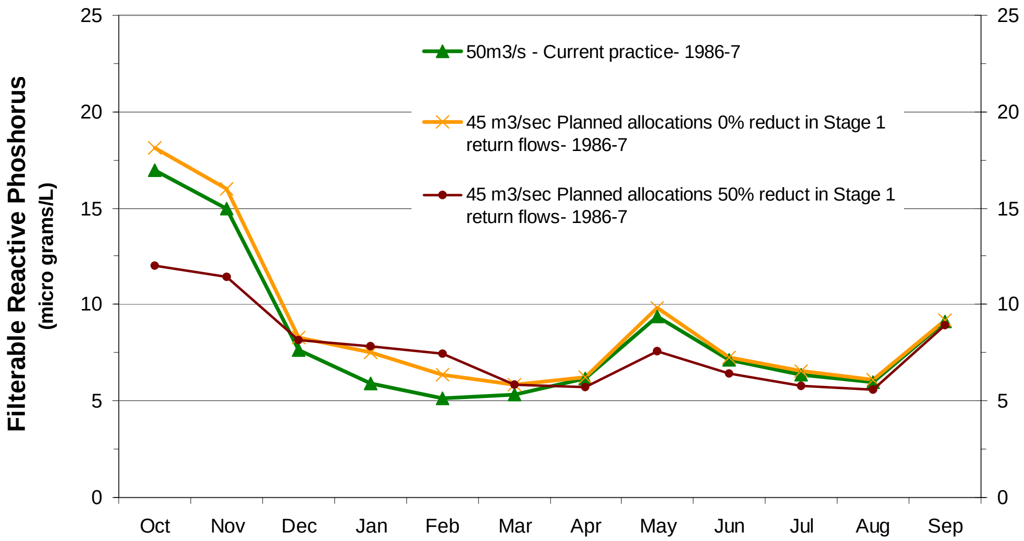
The highest nutrient concentrations in watercourses and lakes of the region generally occur at the end of the dry season when flow rates and levels are low and water temperatures high. They can also occur when the first small flows of the wet commence. The dry season FRP concentrations under the proposed allocations, when combined with a 50 per cent reduction in drainage return flows, are again lower than those under current practice (Figure 28 (b)). Again, the reduced hydro-electric releases increase the FRP concentrations during the wet season in a similar way to the TP values but to a smaller degree.

During droughts, nutrient concentrations are expected to reduce relative to median flow conditions (Figure 28). This is because irrigation return flows during periods of restrictions are likely to reduce in proportion to the water allocated. The modelled reductions in nutrient return loads are greater than the reduction in EWP releases, causing the lower concentrations. Significant reductions in wet season TP concentrations also occur. This is a consequence of a much smaller proportion of the total nutrient load coming from the Dunham River in the drought year.

[57] Wet season taken as December to March in this case as significant nutrients from surplus irrigation can contribute in November.



(a) Total Phosphorus



(b) Filterable Reactive Phosphorus

Figure 28 Estimates of phosphorus concentrations in the lower Ord River

Under the allocations and licensing arrangements proposed in this plan, dry season phosphorus concentrations are unlikely to cause blue-green algal blooms. Concentrations are relatively low (<10 µg/L FRP for all but October and November) and hydraulic residence times in the pools are less than 24 hours (Trayler *et al.,* 2006). While some increase in macrophyte growth might be expected in shallow areas, this is more likely to occur from less frequent flooding than lower river levels or increased nutrient supply. Greater accumulation of stands of *Typha* and other macrophytes are likely because of longer periods between large flow events with sufficient power to scour them away periodically.

Note that the increase in dry season concentrations caused by the 5 m^3/sec reduction in dry season flow rate is more than offset by the decrease resulting from the 50 per cent reduction in tailwater returns expected from Stage 1 areas by 2009 (Figure 28). Achieving this target is perhaps the most important element of improved management being expected of Stage 1 irrigators (see Section 8.4.1).

9.3 The lower Ord geomorphology and ecology

Although addressed in part when developing the interim EWR and EWP (Section 3, Section 4 and Appendix 3), this section summarises the likely changes to lower Ord geomorphology and ecology from the flow regimes (Section 9.1) expected after the allocations of this plan are licensed.

9.3.1 Channel dynamics and sedimentation

The flood frequency characteristics of the lower Ord River will not change significantly from the current situation (see Section 9.1.2 and Figure 26). The low energy, relatively constant dry season flows will continue to provide a favourable environment for colonisation of channel margins and sediment bars by aquatic and riparian vegetation and thereby encourage further sediment deposition and gradual stabilisation of vegetation sediment complexes. These trends in sedimentation and channel encroachment, which are described more fully in Section 2.4.2, may result in a more confined and narrow channel.

9.3.2 Aquatic and riparian vegetation

The aquatic and riparian vegetation composition and extent in the lower Ord have been markedly altered by the post-regulation changes in the hydrology (Section 2.4.2). It is unlikely that changes to the flow regime described under this plan will cause any further loss of species or diversity from the current vegetation. However, there may be a gradual shift in composition and extent in some components of the vegetation.

Given that the frequency of peak flow is not expected to alter markedly, the vegetation that occurs high on the banks or on the old floodplains is not expected to be affected by the changes under this plan. The high bank vegetation is dominated by mature trees with very few younger trees, a reflection of the limited inundation of these areas since the Ord River Dam was constructed. While there is recent evidence of sapling establishment on the base of the old riparian zone after the 2000 flood flows (Start *et al.*, 2002), the tree species in these areas are expected decline in the long term, given that the current flood regime is unlikely to change significantly in the future.

Vegetation communities that occur on stable rock bars are not expected to alter markedly, although reduced dry season water levels may enable some colonisation of new habitat. The vegetation communities occurring on channel margins (including paperbarks and *Pandanus species* communities) are likely to migrate towards the new baseflow channel margins by colonising previously shallow inundated areas. As this occurs, and the outer margin of the substrate dries out, some re-adjustment of the riparian vegetation may occur in the outer margins.

However, any changes that may be induced by the lower dry season flows allowed by this plan are expected to be secondary to changes expected between years caused by the intervening wet season flows. Significant changes in riparian vegetation between years have been observed since 2000 and related to the magnitude and sequencing of some of the largest floods observed on the lower Ord River since regulation (Trayler *et al*., 2006). The riparian vegetation community will continue to respond in a dynamic way to the future sequence of wet season flows, especially those generated from the (substantially) unregulated catchment of the Dunham River.

The distribution of submerged and emergent macrophytes will also change in response to the lower dry season flows, as their extent is dependent upon water depth, substrate and flow velocity. Emergent macrophytes are likely to colonise sites that are currently too deep for them, but may be excluded from sites that are left above the new dry season base flow level. However, like riparian vegetation changes, aquatic vegetation changes caused by wet season flows are expected to be significantly larger than any changes caused by reduced dry season flows. Section 2.4.43 described the major scouring effect of the March 2000 flood and the subsequent high wet-season flows on the aquatic and riparian vegetation of the lower Ord River. Large (infrequent) wet season flows in the lower Ord River are expected to continue to scour aquatic vegetation from the lower Ord River on occasions. The rate of re-colonisation of aquatic vegetation is likely to depend more on the subsequent wet season flows and minor differences in dry season flow rates.

9.3.3 Estuarine crocodiles and waterbirds

The likely impacts of the interim EWR and EWP on invertebrates and fish are discussed in Section 3.3 and 4.4, and Appendix 3 and not repeated here. The Scientific Panel also considered the effects on estuarine crocodile populations and waterbirds (WRC, 2000a) in the lower Ord River. They considered that the interim EWR would not alter estuarine crocodile populations and would have a neutral or beneficial effect on in-stream use by waterbirds.

9.4 Ramsar wetlands

As summarised in Table 5, the Ramsar wetlands of the area provide open water, adjacent fringing vegetation and (in some areas) shallow water and exposed mud flats that provide habitat and food sources for hundreds of bird species, estuarine crocodiles and an unknown number of fish species.

The highly productive nature of these wetland systems and their inherent diversity is likely to be related to their hydrology. Therefore, the effects of the proposed allocations on the water levels in Lakes Argyle and Kununurra and in the estuarine areas of the lower Ord River have been evaluated. Peak levels and instantaneous flow rates also affect inundation of the floodplain, the interaction with local runoff from the Parry Creek Nature Reserve and the mangrove communities of the lower Ord floodplain. Both of these aspects are discussed below.

9.4.1 Level changes in Lakes Kununurra and Argyle

Lake Kununurra is managed to have as stable water level as possible. This is to provide a constant head for diversion of water down the M1 Supply Area and it is not planned to change this. When additional water is either diverted for irrigation or released downstream to maintain the EWP, additional water is released from Lake Argyle to maintain the same level. While the water flow entering into and out of Lake Kununurra may change in velocity under this plan, there should be no measurable impact on the ecosystems that Lake Kununurra supports.

Figure 29 shows the pattern of monthly lake levels in Lake Argyle over the simulation period for the current and proposed allocation situations. Fluctuations caused by the hydrologic variability dominate the changes through time and differences caused by the proposed allocations are secondary. The median of the differences in monthly levels between the current and proposed situations is 1.3 m. Smaller differences are common when the lake level is near or above the spillway height. The largest differences exceed 3.0 m but occur at low reservoir levels when the surface area is already substantially reduced. These largest differences only occur for less than 2.5 per cent of the time.

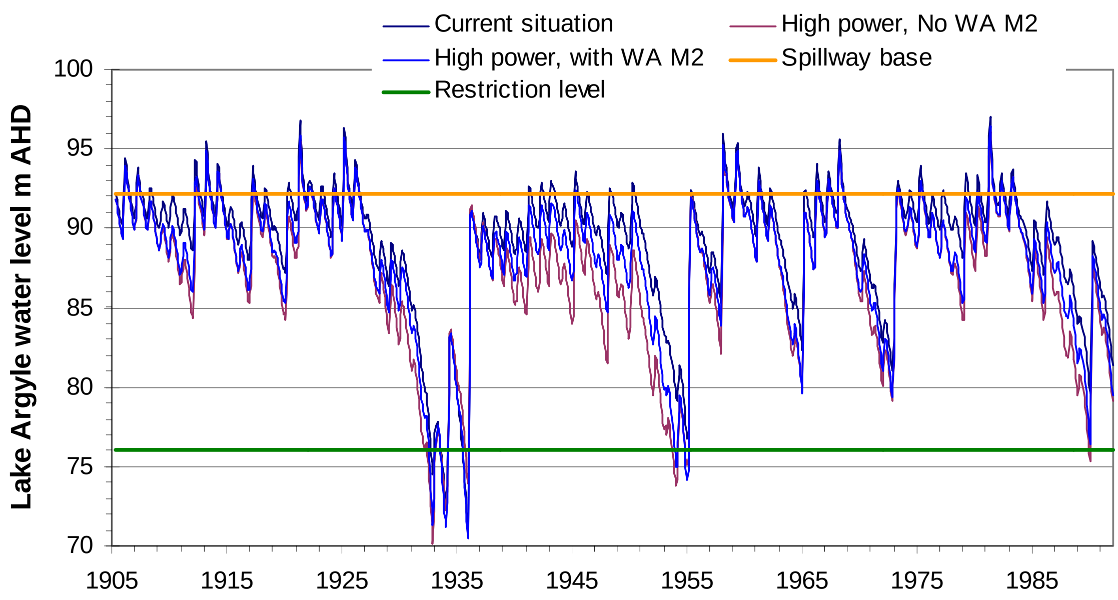


Figure 29 Simulated monthly levels in Lake Argyle under current and proposed allocations

The Ramsar nomination of Lake Argyle recognised that the primary management purpose of this man-made wetland was water supply (Watkins *et al*., 1997). They also recognised that the ecological configuration of Lake Argyle is still evolving and that the variable nature of this system is a feature of its ecological character. Given the similarity of level fluctuations in Figure 29 there is expected to be little or no change in Lake Argyle's value as a habitat for migratory birds listed under international conservation treaties.

9.4.2 The lower Ord River floodplain

As discussed in Sections 2.4.1 and 9.1.2 the flood regime has been dramatically altered by the Ord River Dam and the additional allocations of this plan will only marginally affect the current flood frequency characteristics of the lower Ord River. The changes to the 1 in 10 and 1 in 20 year ARI flood peak are not able to be shown at the cross-sectional scale of Figure 9. Changes in inundation areas would also be small and not within the accuracy of the flood modelling and mapping. Minor differences in the frequency of inundation will no doubt occur, but will be difficult to identify or measure.

The ecosystems of the Ord River floodplain have been adapting to the reduced flooding regime since the Ord River Dam was constructed and will continue to do so. The Parry Creek Nature Reserve was nominated as a Ramsar wetland, principally for its value as habitat for Magpie Geese *(Anseranas semipalalmata)* breeding and migratory shorebirds. The site, which is recognised as one of the five most important wetlands in WA for migratory shorebirds, was nominated in the early 1990s, some 20 years after the Ord River flood regime changed. These high wetland values occur despite the fact that regular flooding from the lower Ord River has not occurred since the early 1970s. The dynamics of the wetland systems of the reserve appear to be driven by the local surface water hydrology and hydrogeology. Local rainfall and stream flow from Parry Creek is sufficient to inundate the main Parry Creek floodplain and lagoon systems each wet season. While drainage and evaporation reduces the areas of open water through the dry season many of the lagoons and swamps persist to the next wet season, much as they probably did before regulation of the Ord River. The proposed allocations will make no significant change to these processes and it is therefore likely that the present waterbird and wetland values will be maintained.

Other important ecosystems in the Ord River floodplain area include the mangrove communities in the saline estuarine sections of the lower Ord River. As noted in Section 2.5.3, mangrove stands appear to have been enhanced by the reduction in Ord River flooding. Mangrove communities are adapted to a wide range of brackish to saline conditions and favour habitat with a large tidal range. Only minor changes in the salinity of Cambridge Gulf will occur as a result of the additional diversions (Section 9.5) and no measurable change to their local environment is expected.

9.5 Changes in Cambridge Gulf

Concern has been expressed about the further reduction of fresh inflow to Cambridge Gulf and its additional effect on the Gulf's ecosystem processes. Changes that have already been observed were discussed in Section 2.5.3. Estimates of the changed inflows and their effect on the salinity of the estuary are discussed below.

9.5.1 Inflow volumes

The effects of the current and proposed allocations of Ord River water on the inflows to Cambridge Gulf are summarised in Table 17. While the Ord River is the largest input, four other large unregulated rivers also contribute (Figure 12). These are the King, Forrest, Durack and Pentecost Rivers. Estimates of the annual inflows under dry, median, mean and wet conditions[58] are included in the table for the natural, current and proposed conditions. Under natural conditions the Ord River contributed 58 per cent of the total annual inflow. As a result of regulation and current operation this has been estimated to reduce to 47 per cent and 49 per cent under median and mean inflow years respectively. Under the allocations of this plan the contribution would reduce to 42 per cent and 44 per cent respectively. Note that in the dry years the contribution from the Ord River under the proposed allocation is larger than under natural conditions (64 per cent compared with 58 per cent). This is a direct consequence of the regulation and EWP and releases for power generation in excess of the irrigation diversions.

9.5.2 Salinity Levels

The effects of these reductions on the salinity of Cambridge Gulf water were estimated in the following way. While full hydrodynamic modelling of tidal and river mixing is possible (Wolanski *et al*., 2001) a simpler tidal forcing and mixing volume model was developed. This used the different river inflows characteristic of the allocation situations as direct input. It was based on the knowledge that the strong tidal currents of the estuary generate a well mixed water body each tidal cycle (see Section 2.5.3). A two-stage mixing volume approach was used to reflect the mixing of river water with estuarine water each tidal cycle. River input during the ebb tide cycle was added to the salt and water in the estuary at low tide and assumed to mix fully. At the end of the flood tide cycle the river input was added to the salt and water in the estuary at high tide and also assumed to mix fully. The main unknown factor was the exchange of salt (and water) with the outer ocean as reflected in the salinity of the incoming estuarine water on each flood tide. The incoming flood tide salinity was made a linear function of the estuarine salinity on the previous tidal cycle and the salinity of sea water. The degree of sea water mixing was determined by assuming that a salt balance would be achieved over a full yearly cycle under median inflow conditions. As the computations were carried out for each ebb and flood tide, estimates of river inflows at this time scale were also required. Typical monthly distributions of the annual volumes in Table 17 were adopted based on the unregulated and regulated flows used or calculated in the

[58] As measured by estimates of the 10^{th}, 50^{th}, mean and 90^{th} percentiles of the annual inflow.

reservoir simulations. These were subdivided to provide river inputs over the average 60 flood and 60 ebb tides each month. Regulated flows were distributed uniformly, while unregulated flows were made proportional to daily flows of the Ord River prior to regulation[59].

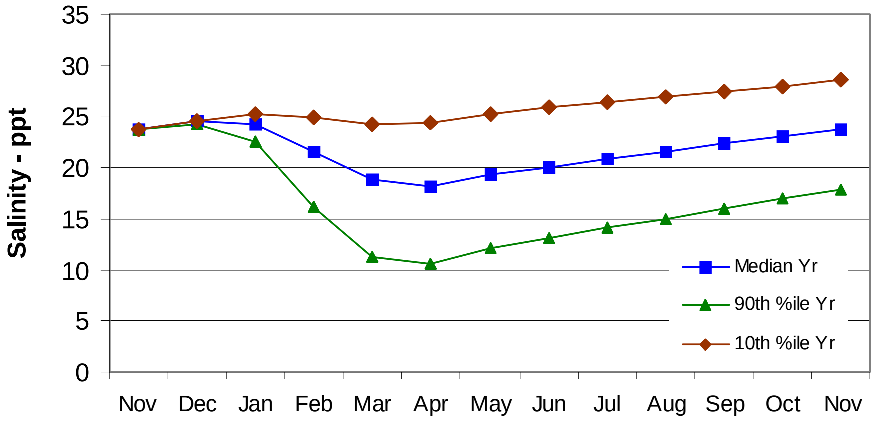
[59] The ratios of daily flows to average monthly flows were based on the Ord River at Coolabah Pocket for the typical wet season months of 1961.

[59] The starting salinity in each case was calculated by assuming that median inflow volume for each inflow condition was fully mixed with sea water in a volume of 22,500 GL This is about 45 % greater than the average high tide volume (15,500 GL) and assumes that mixing with ocean water (at 33 ppt) extends out into Joseph Bonaparte Gulf. The average low tide storage used was 8,500 GL.

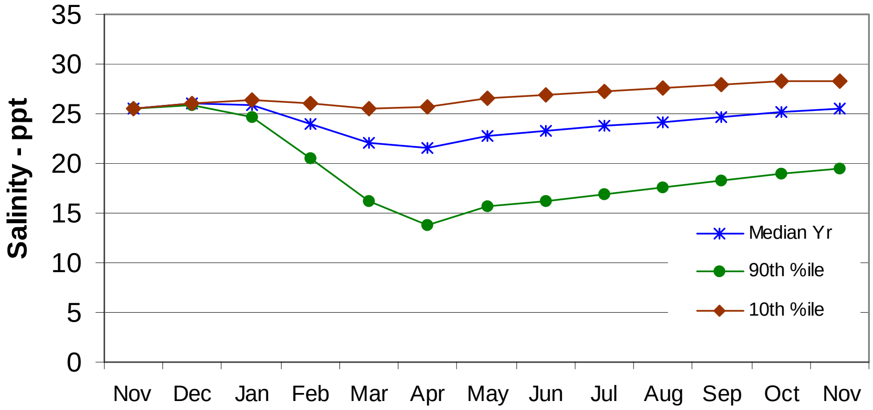
Table 17 Inflows to Cambridge Gulf under natural, current and proposed conditions

Inflow Conditions	**Statistical properties of annual stream inflows**			
	10th %ile GL	**Median GL**	**Mean GL**	**90th %ile GL**
Natural (Unregulated) Conditions				
Ord River @ Kununurra Diversion Dam	940	3130	4090	8090
Ord River @ Cambridge Gulf Mouth	1030	3670	4750	9280
King River	29	102	132	258
Forrest River	83	295	382	746
Durack River	477	1700	2200	4298
Pentecost River	155	552	715	1397
Total -To Cambridge Gulf	1774	6319	8179	15 979
Ord Inflow as % of Total	58 %	58 %	58 %	58 %
Current Conditions				
Ord River at Kununurra Diversion Dam	1681	1840	2679	4993
Ord at Cambridge Gulf Mouth	1771	2380	3339	6183
King River	29	102	132	258
Forrest River	83	295	382	746
Durack River	477	1700	2200	4298
Pentecost River	155	552	715	1397
Total -To Cambridge Gulf	2514	5029	6768	12 882
Ord Inflow as % of Total	70 %	47 %	49 %	48 %
Under the allocations of this plan				
Ord River at Kununurra Diversion Dam	1253	1348	2074	4109
Ord at Cambridge Gulf Mouth	1343	1888	2734	5299
King River	29	102	132	258
Forrest River	83	295	382	746
Durack River	477	1700	2200	4298
Pentecost River	155	552	715	1397
Total -To Cambridge Gulf	2087	4537	6163	11 998
Ord Inflow as % of Total	64 %	42 %	44 %	44 %
Gulf Inflow as % of Natural Flows	118 %	72 %	75 %	75 %
Gulf Inflow as % of Current Conditions	83 %	90 %	91 %	93 %

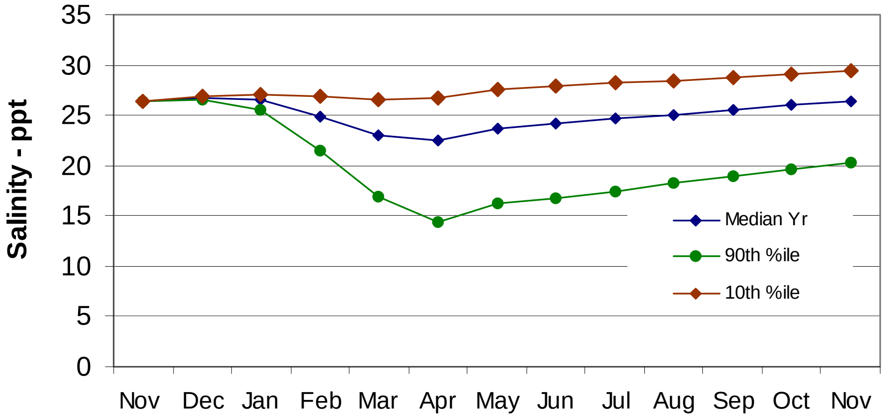
Figure 30 shows indicative salinities in Cambridge Gulf over a 12-month (water year) cycle for the range of inflow conditions of Table 17. Indicative salinities at the end of one and two years of these inflow conditions are summarised in Table 18.



(a) Natural (unregulated) conditions



(b) Under current conditions



(c) Under conditions allowed by this plan

Figure 30 Cambridge Gulf salinities under different inflow conditions and degrees of Ord River regulation

Table 18 Cambridge Gulf salinities

Cambridge Gulf inflow conditions	Salinities after inflow period - ppt		
	Natural	Current conditions	Allowed by this plan
After a year with median inflows	23.7	25.6	26.4
After a dry inflow year - 10th percentile	28.5	28.2	29.4
After two successive 10th percentile (dry) years	30.4	29.3	30.7
After a wet year – 90th percentile	17.8	19.5	20.3
After two successive 90th percentile (wet) years	17.2	18.4	19.5

Larger changes in Cambridge Gulf salinities occur between years, in response to the natural variability of inflows, than occur from changes in the flow of the Ord River. This is apparent from Figure 30 which shows that similar ranges of salinities are predicted under (a) unregulated conditions, (b) current conditions and (c) conditions allowed by this plan.

The modelling demonstrated the seasonal dilution effects of fresh river inflow in influencing the salinity of Cambridge Gulf. Under average and wet year inflow conditions, the salinity of Cambridge Gulf water is progressively diluted by river inflows until April each year (Figure 30). During the following dry season, when fresh inflow is restricted to releases from the Kununurra Diversion Dam, salinities gradually rise as flood tides bring in sea water from the Joseph Bonaparte Gulf and the Timor Sea. Very little dilution was modelled during wet seasons of dry (10th percentile) years.

The lowest concentration simulated (10 ppt) occurred at the end of the wet season in a year with a 90th percentile inflow under pre-regulation conditions. Equivalent salinities were estimated to be about 15 ppt under current conditions and allocations allowed under this plan. The difference reflects the effect of reductions in wet season inflow volumes in wet years as a result of regulation[60]. Differences between minimum salinities under current conditions and conditions allowed by this plan are much smaller, being usually less than 1 ppt in comparable inflow years.

Average salinities in Cambridge Gulf (as reflected by salinities after a year with median inflows -Table 18) only differ by 2.7 ppt between natural conditions and under conditions allowed by this plan. The difference between current conditions and conditions allowed by this plan is only 0.8 ppt. The effect of the current dry season releases from Lake Argyle is apparent in dry years although the effect is small. The current conditions reflect slightly lower salinities (by 0.3-0.9 ppt) in dry years than pre-regulation levels. There is more flow downstream of the Kununurra Diversion Dam[61]

[60] It also reflects the simplifications made. Lower salinities would be expected just after large floods. However, to improve these estimates much more data intensive hydro-dynamic modelling and field work would be required.

[61] A result of the hydro-power and navigational releases being significantly greater than the water diverted for irrigation.

relative to pre-regulation conditions (Table 17) in these dry years. This is sufficient to cause lower Cambridge Gulf salinities at the end of the dry season than under pre-regulation conditions even though the average starting salinity was 1.9 ppt higher. Under the proposed allocations, salinities at the end of dry seasons are marginally higher than pre-regulation values (by 0.9 ppt after the first year and 0.3 ppt after the second). In this case the flows downstream of Kununurra Diversion Dam[62] are not sufficiently large to lower end of season salinities to values less than pre-regulation levels.

In summary, Cambridge Gulf salinities are not significantly affected by the proposed allocations, however the frequency of salinities less than about 15 ppt have probably decreased as a result of construction of the Ord River Dam. These changes are primarily due to the effect of the Ord River Dam on reducing wet season volumes and the frequency of large floods on the lower Ord River (Section 2.4.1 and Section 9.1.2)[63].

9.5.3 Environmental implications

The less frequent occurrence of low salinities in Cambridge Gulf may well have affected some of the aquatic species mix over the last 30 years. However, it is unlikely that the additional changes expected under the proposed allocations would have any significant further effect. Most species that live in estuarine ecosystems are adapted to large salinity changes (from near fresh to sea water salinities). Given this, and the fact that there are other unaffected arms of the Gulf, it is highly unlikely that any species would be completely lost to the Cambridge Gulf as a whole.

The other ecological effects of the dam construction were discussed in Section 2.5.3. Sediment accumulation in the Ord River estuary, associated changes in mangrove stands on the river banks and islands, and reduced catches of banana prawns in the Ord River arm of the Gulf were identified. The changes to sedimentation are expected to continue until the river and estuary establish a new dynamic equilibrium under the reduced flood regime. This could take 50 years.

The additional irrigation allocations provided for in this plan are not considered to significantly alter these sedimentation processes. Again, however, species abundance and richness in the estuary may well change over time as the local ecosystems adapt to these changes. This continued adaptation over time is unlikely to lead to any loss of species or reduced overall biodiversity.

The modelling also confirmed that further diversions of water from the Ord River would not significantly impact the salinity of the Ord River estuary. This was of concern to proponents of a potential prawn farm near Wyndham who were intending to use water from the Ord River estuary as the main water supply for the prawn farm. The modelled salinities of Figure 30(c) reflect the likely supply salinities of water on the incoming tide

[62] The downstream flows are less than the current situation because of the lower EWP (45 m^3/sec), higher irrigation diversion and lower hydro-power releases.

[63] Note, however, that modelling of the dynamics of specific flood events was not carried out in this exercise.

in the Ord River estuary. Overall, salinities average around 25 ppt during an average year (the optimum concentration for healthy prawn growth under farmed conditions). Except following very large (infrequent) floods, incoming tidal salinities are expected to remain above 15 ppt. In dry years (1 in 10), salinities could rise to around 30 ppt and remain at this level for most of the next year if a similar dry year occurs.

9.6 Concluding remarks

Development of the current plan commenced when knowledge of the ecology of the lower Ord River was very limited. While improved considerably in recent years, our ecological knowledge remains imperfect, and consequently, predictions of ecological change in the lower Ord River still contain many uncertainties.

In attempting to limit these uncertainties and establish a sound and precautionary approach to future water allocations, the Department took advice from the EPA, the Scientific Panel, the Community Reference Panel and in-house specialists in aquatic biology and hydrology during the development of the plan. As more has been learned about the river’s ecology the limitations of relying on wetted perimeters as measures of in-stream habitat became increasingly apparent. Recent improvements in knowledge of the river’s hydrology and ecology will be incorporated into management as soon as possible (see Section 10).

Despite the uncertainties and limitations of the current approach, the Department considers that the small change in dry season flows allowed for under the plan, will avoid any unacceptable change in the ecology of the lower Ord River. The impact on in-stream habitat and water quality is expected to be minor, given the continuous nature and limited reduction in dry season flows being permitted, and the improved irrigation practices in Stage 1 areas that are expected to significantly reduce the nutrient load being discharged to the lower Ord River during the dry season. Any changes in the river’s ecology that may be observed in the future will be difficult to distinguish from changes caused by natural variations in wet season flows of the lower Ord River, especially those generated from the (substantially) unregulated catchment, downstream of the Ord River Dam.

As no significant increase in regulation of Dunham River flows is to be allowed, the current (post-dam) flood frequency characteristics of the lower Ord River will be maintained. Hence, the current in-stream and floodplain environments, their values and the functional exchanges between them should remain unchanged. No measurable impact is therefore expected in the range of aquatic fauna found in the lower Ord River under the allocations of this plan. In addition to maintaining the present day ecological values at a low level of risk, the majority of the recreational, tourism and Aboriginal values of the system are expected to be maintained.

10 Reviewing and updating this plan

The need to update this plan and determine additional irrigation allocations to support the expansion of the M2 Supply Area into the NT has been noted throughout this report. This Section describes the key elements that require updating to enable a new allocation plan to be prepared over the next two to three years.

10.1 Updating the hydrology of the Ord catchment

Stream flow, rainfall and reservoir operational records (to 2005), with daily rainfall runoff modelling techniques (Bari and Rodgers*,* 2006), are being used to update the hydrologic characteristics of the Ord River catchment. A set of updated stream flow data sets (extending for 99 years) will form the main hydrologic input for a further round of reservoir simulations to guide revision of the allocation strategy of this plan.

These studies have already shown that in the last 13 years, inflow to the Ord River Dam has been 75 per cent greater than the long term data set used in this plan.

10.2 Reviewing the current EWR and licensing the first phase of the M2 Supply Area

The information summarised by Trayler *et al. (2006),* together with updated hydraulic and hydrologic modelling, has enabled a revised EWR for the lower Ord River to be drafted (Braimbridge and Malseed, *in prep.*). When finalised, the updated hydrology and EWR regime will be used, in conjunction with the sustainable diversion limits of this plan, to assess the licence application from the water service provider for the first stage of M2 Supply Area development[64] and establish compatible water release rules for the ORDHP Station. As part of the assessment the Department will address input received from key stakeholders and the community on the licence application and this plan, and release a report on the proposed licence and water release rules. The report will inform the EPA and DEH on how the water management aspects of the first phase of the M2 Supply Area development are to be managed, and used in their environmental impact assessment of the development.

10.3 Updating the current EWP and management plan

When the remaining portion of the M2 Supply Area in the NT is to proceed, the updated hydrology and EWR regime will be used to inform further community and stakeholder consultation to refine the EWP, review and update the allocations of this plan.

[64] Under the provisions of the RIWI Act applicants are required to advertise their licence application. The environmental effect of granting the licence is expected to be assessed by the EPA under the provisions of the Western Australian EP Act, and the Commonwealth Department of Environment and Heritage under the provisions of the EPBC Act.

The process proposed to assess the M2 Supply Area licence, refine the EWP regime and update the allocations of this plan is outlined on the back page of this document under the heading “Where to from here?”.

Appendices

Appendix 1. The Ord River Irrigation Project

A1.1. Initial planning and funding

The Western Australian (WA) Government made its first submission to the Commonwealth Government for financial assistance to develop the Ord River in 1949. After further submissions during the 1950s, the State Government obtained financial support from the Commonwealth Government in August 1959 for the construction of the first of four stages of the Ord River Irrigation Project. The first stage consisted of construction of a diversion dam, distribution and drainage systems to service 12,100 ha of irrigation farmland on the flood plain to the east (Ivanhoe Plain) of the river. Stage 2 included construction of a large dam, 56 km upstream in the Carr Boyd Ranges, to create sufficient storage for a reliable water supply for the Stage 1 farmland and for up to a further 60,000 ha of irrigable land. As originally planned, Stage 2 also included development of 2,200 ha of serviced farmland on Packsaddle Plain to the west of the river. Subsequent stages involved development of additional irrigation supply areas as required and construction of a hydro-electric power station (up to 60 MW capacity) at the main storage dam (Le Page, 1986).

A1.2. Establishment and the early years

A 1.2.1. Water infrastructure

The Kununurra Diversion Dam was built between 1961 and 1963. The initial five irrigation farms on the Ivanhoe Plain were first supplied from Lake Kununurra in May 1963. Lake Kununurra is the reservoir formed behind the Kununurra Diversion Dam. The lake stores 98 GL of water at its normal operating level of 41.6 m AHD. Additional farmers took up land over the next four years, with rated land in the Ord Irrigation District (the District) reaching 9,100 ha by 1967. Investigations and design of the Ord River Dam proceeded during the 1960s and tenders were called for construction in 1968, after the Commonwealth Government committed financial assistance for the second stage of the Ord River Irrigation Project in late 1967. Construction to allow the dam to store water in Lake Argyle commenced during the dry season of 1969, and was sufficiently completed in November 1971. The first overflow from Lake Argyle occurred during the third wet season (1973-74) when water levels exceeded the then full supply level of 86.2 m AHD (storage 5,800 GL). The Packsaddle Plain farmland, drainage and distribution systems were completed by 1973. The establishment and operation of this infrastructure is documented in the Engineering Returns and Statistics of the Public Works Department and Water Authority of WA within the financial years 1961-62 and 1986-87. The key aspects presented in Section A5.1, and Figures A1.1 and A1.2.

A 1.2.2. Irrigated agriculture during the first 25 years

While the first two stages of the original project had been effectively established by 1973, irrigators were struggling financially. Expected to be the most profitable crop in the District, cotton had been grown extensively during wet seasons since 1964-65. However, by the 1973-74 season costs of controlling pests had become prohibitive and many irrigators abandoned their farms as their cotton crops failed (Le Page, 1986). Virtually no cotton crops were grown during the following season, and the area irrigated reduced to 3,500 ha, only 34 per cent of the rated area of the District. The area under irrigation remained low for many years, averaging a low 41 per cent for the 12 years to 1986-87. A range of alternative crops, grown mainly during the cooler dry season were tried over this period. Many proved non-commercial, especially those grown in the late 1970s and early 1980s (rice, sunflower for example). As foreshadowed by critics of the project, the remoteness of the District exposed farmers to high transport and supply costs. These reduced the commercial viability of many potential crops and became a major constraint to overcome before new farmers could be attracted to the District. To minimise some of the cost pressures caused by remoteness, farmers turned to growing fodder crops to complement the cattle industry in the East Kimberley. The crops were either grazed directly or harvested and the produce sold locally, to provide high quality supplementary feed to fatten cattle prior to export. From the mid 1980s, new horticultural crops were introduced and showed early commercial promise. By the start of the next decade, and for the first time since the mid 1970s, the future of the District began to look more promising.

A1.3. Consolidation and development during the 1990s

A 1.3.1. Irrigated agriculture from the early 1990s

Irrigation in the District increased during the 1990s as the horticultural industry expanded and sugarcane growing commenced. Better roads and improved protection of produce during transport made growing horticultural crops more attractive. Crops were grown and harvested out of season from traditional growing areas in southern Australia, and the produce delivered to major Australian markets in good condition and attracted top prices. Cucurbit crops, such as melons and pumpkins, were introduced and bananas and mango plantations established. With sugarcane trials indicating high yields, growers' plantations were established and sugar production commenced in late 1995. With confidence in the future of the District returning, actions commenced to revive earlier plans for the development of new Stage 2 areas (see Section A1. 4 below).

By the year 2000, the area of developed farmland[65] with access to Ord River water had grown to about 15,000 ha. This area of developed farmland collectively became known as the Stage 1 areas[66]. Since 1997 between about 10,000 and 12,200 ha of this area has been irrigated. Between the irrigation seasons of 1996-97 and 2004-05 (defined as starting from April each year) the volumes supplied on farm have fluctuated between 150 GL and 205 GL and are contrasted with the much lower figures reported during the first 25 seasons.

[65] Some small holding land releases and sub-divisions had occurred since the Packsaddle area was completed in 1973.
[66] The Packsaddle Plain area is included as a Stage 1 area, although was originally part of the second stage of the original 1959 Ord River Irrigation Project.

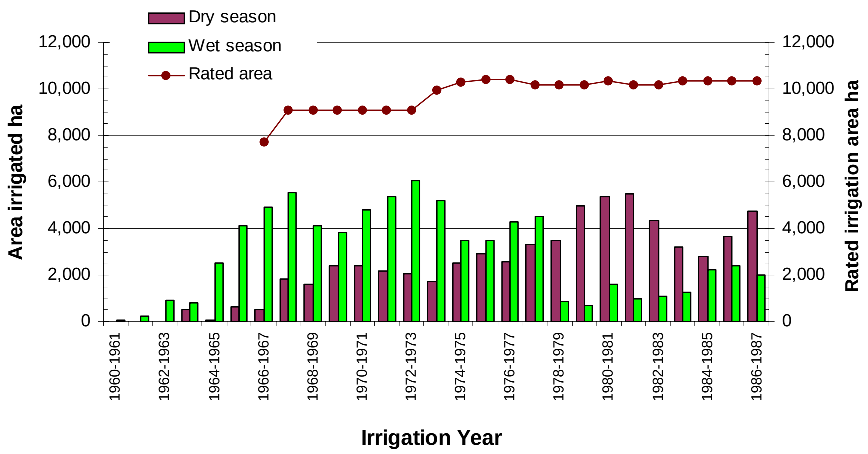


Figure A1.1 Water entering Ord Irrigation District and minimum volume stored in irrigation season

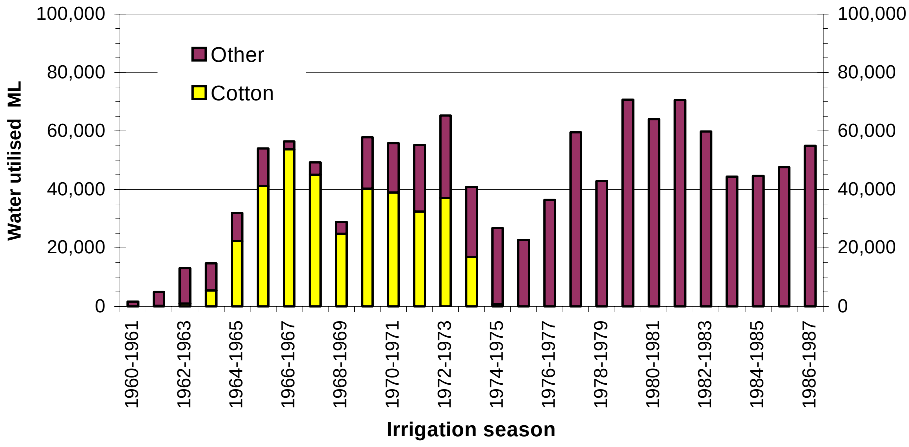


Figure A1.2. Volume of water used on-farm to irrigate cotton and other crops

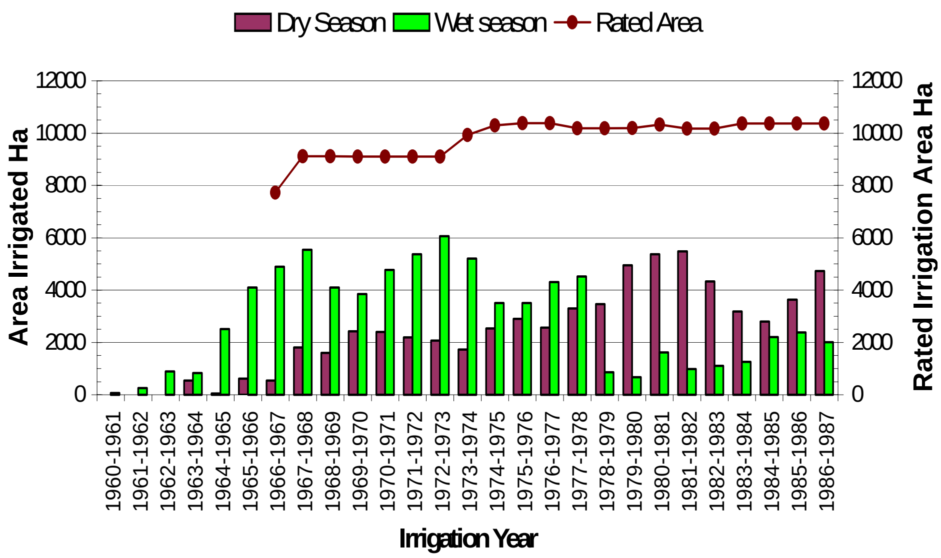


Figure A.1.3 Areas irrigated by season and rated irrigation land in the District

As discussed in Section 1, Ord Hydro Ltd operates their Ord River Dam Hydro- electric Power (ORDHP) Station through a Water Supply Agreement made with the Water Authority of WA in 1994 under the *Ord River Hydro Energy Project Agreement Act 1994.* These were developed prior to the formation of the Water and Rivers Commission (the Commission) and before Environmental Water Provisions (EWP) became an integral part of surface water allocation planning.

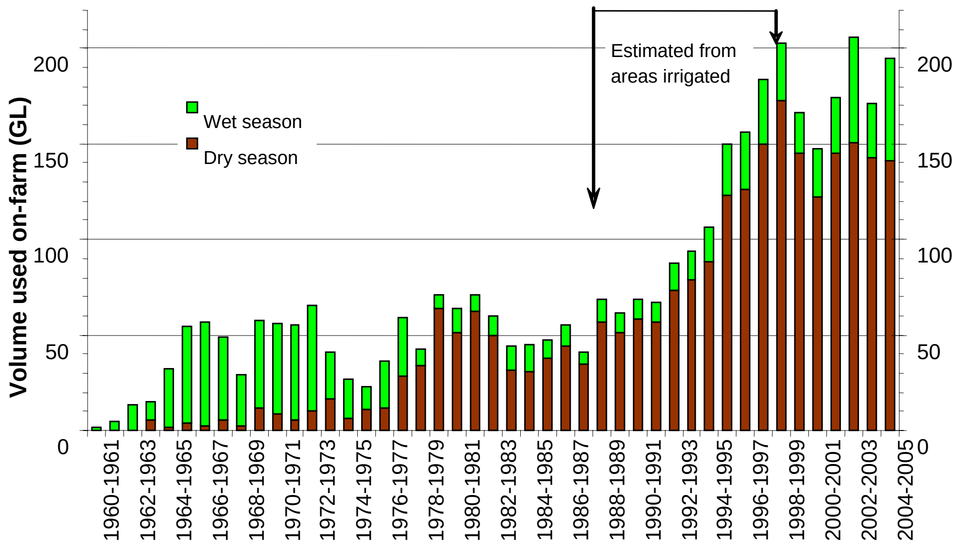


Figure A1.4. Water volumes supplied (utilised) on-farm

The *Ord River Hydro Energy Project Agreement Act 1994* establishes that the water for the project is to be obtained in accordance with the provisions of the State's water legislation, and a Water Supply Agreement between Pacific Hydro Ltd and the Water Authority of WA. Under the Agreement Act the State may not unduly prejudice Pacific Hydro's activities under the Agreement by granting a water right without consultation and consent of the company.

The Water Supply Agreement (WSA) with Pacific Hydro Pty Ltd is now administered by the Water Corporation although the water allocation aspects are regulated by the Water and Rivers Commission through Water Corporation's Ord River Dam licence. The WSA enables Pacific Hydro Ltd to release water through their power station to generate 210 GWhrs/yr in all but drought conditions (when the water level in Lake Argyle exceeds 78 m AHD). The releases are subject to water release rules that have the multiple objectives of supplying water for electricity generation, irrigation, in-stream uses and other demands. The WSA includes a provision to revise the water release rules after the first 1,015 GWhrs was sold to industry (occurred in 2003), by agreement of both parties. While the WSA does not over-ride the duties and powers of the Commission under the RIWI Act it includes clauses designed to protect Pacific Hydro Ltd from being disadvantaged in the exercise of those powers.

That is, under the Agreement Act and the WSA, the State is required to negotiate and seek the consent of Pacific Hydro Pty Ltd if the:

- Water and Rivers Commission or the Water Corporation propose changes to the WSA, or
- State proposes to issue a water licence which, if issued, would unduly prejudice the operation of Pacific Hydro Ltd's ORDHP Station.

Negotiations are ongoing with Pacific Hydro Pty Ltd over ways to update the release rules of the WSA to provide for the allocations of this plan.

A1.4. Stage 2 development proposals

In the mid 1990s the Department of Resources Development (now known has the Department of Industry and Resources), the agency responsible for coordinating development projects in WA, sponsored a series of investigative studies and conceptual designs (DRD 1995, 1997a, 1997b) to update earlier development plans. These provided a base for the Governments of WA and the Northern Territory (NT) to call for expressions of interest from the private sector to consider financing the expansion of the irrigated areas.

A 1.4.1. The M2 Supply Area Sugar Project

In 1998, a joint venture of Wesfarmers, the Marubeni Corporation and Water Corporation was awarded preferred developer status to investigate the financial and environmental feasibility of a project to develop 33,000 ha of serviced irrigation land on the Weaber, Knox and Keep River Plains to the east of currently developed areas. A new (M2 Supply Area) main channel from Lake Kununurra was to supply water to the area from Lake Kununurra. Most of the M2 Supply Area was to be used to irrigate sugarcane and provide the feedstock for a three million tonne per year capacity sugar refinery. The raw sugar from the refinery was to be exported through the port of Wyndham.

In December 2001, Wesfarmers and the Marubeni Corporation withdrew from their M2 Supply Area Sugar Project. The proponents were concerned about the then low world sugar price, its long term uncertainty and the consequences of these for the likely return on investment from the project. Other uncertainties relating to Aboriginal heritage and Native Title issues and water availability were also of concern.

The environmental impact assessment of the M2 Supply Area Sugar Project was well advanced in December 2001. The Minister for State Development accepted responsibility as caretaker proponent for the development of the M2 Supply Area. In February 2002, the Minister for Environment set conditions on the approval to establish approximately 30,000 ha of serviced irrigation blocks in the M2 Supply Area (Minister for the Environment and Heritage, 2002).

A 1.4.2. Downriver developments- Mantinea Flats

In 1999, the Henry Walker Elton Group was selected as preferred tenderer to investigate the feasibility of developing approximately 4,000 ha of serviced irrigation blocks on Mantinea Flats, between 50 and 70 km downriver from the Kununurra Diversion Dam. However, the company's preferred developer status lapsed when the group went into receivership in 2004.

Appendix 2. The 1999 Draft Interim Water Allocation Plan and EPA advice

This appendix summarises the main features of the 1999 Draft Interim Ord River Water Allocation Plan, the public comments received, and the Western Australian EPA's recommendations on the interim Ecological Water Provisions (EWP) of the draft plan.

A2.1. The 1999 Draft Interim Allocation Plan

The Commission formally released the May 1999 Draft Interim Ord River Water Allocation Plan for public comment in June 1999 (WRC, 1999d).

The plan included a number of principles that were to guide the Commission's approach to its allocations and licensing decisions. The key principles were:

- the Ord River water resource would be managed in a way that enables sustainable development while maintaining defined environmental values;
- in recognition of the inadequate scientific basis currently available for determining environmental flow requirements, interim conservative allocations to consumptive uses were to be made. That is, the precautionary principle would be applied;
- the order of priority for supply would be:
    - environmental provisions;
    - irrigation;
    - hydro-power generation for the East Kimberley electricity grid; and
    - hydro-power generation for the Argyle Diamond Mine.
- within the constraint of provision of water for environmental purposes, water for irrigation should be supplied with a high level of reliability; and
- water releases from the reservoirs would generally serve more than one purpose; e.g. water released from Lake Argyle for irrigation purposes can be used to generate power and may provide for some in-stream needs, including those for navigation, below the Ord River Dam.

A 2.1.1. The proposed allocations

For the environment

As an interim EWP, the Commission proposed that a flow regime in the lower Ord River typical of dry conditions prior to the construction of the dams should always be maintained. The 20th percentile of the pre-dam flow each month, at the confluence with the Dunham River, was selected to reflect dry conditions throughout the year. This approach had been used for other river systems where little ecological data was available to justify a more sophisticated approach (Arthington *et al.,* 1992). It was used for the Ord River to set a minimum EWP until the definition of ecological values could be decided and field-based studies undertaken to determine their Ecological Water Requirements (EWR).

Under this initial EWP constraint, up to 1,500 GL/yr could be diverted downstream of Lake Argyle in 95 per cent of years, implying an allocation to the environment of at least 600 GL/yr[67]. In keeping with the precautionary principle, the Commission was only prepared to set an interim sustainable diversion limit of 1,235 GL/yr. This was considered sufficient to meet the projected needs of irrigation and left approximately 265 GL unallocated. The plan highlighted that the environment had first priority to this water when allocated and indicated its potential value as an additional dry season EWP. Such an allocation would mitigate possible dry season water quality changes in the lower Ord River when additional diversions, to supply new irrigation developments, took place.

To irrigation

The interim sustainable diversion limit available for diversion from Lake Kununurra and the lower Ord River was set at 1,235 GL/yr and allocated for irrigation purposes. This would enable approximately 50,000 to 55,000 ha to be irrigated in the region in any one year depending on the crops grown. It was considered sufficient to provide enough water to meet water demands in the current irrigation area, the M2 Supply Area and development of an additional 10,000 ha downriver.

The existing Stage 1 irrigators were to be allocated 300 GL/yr. The allocation was considered sufficient to water the then current cropped area plus an allowance for additional irrigation on two large undeveloped locations (a total of 11,780 ha). Provision was made for 60 per cent of the total to be sugarcane and a generous allowance was made for distribution losses (33 per cent of the water diverted). The Commission also indicated in the plan its intention to work with the Ord Irrigation Co-operative to:

(a) reduce the risk of water-borne contamination events occurring in the lower Ord River caused by current irrigation practices; and

(b) to improve the distribution and on-farm efficiency of water used.

A timetable to achieve these improvements was to be negotiated between the OIC and the Commission before licence conditions were finalised. The plan also acknowledged that additional allocations to irrigation would be considered provided that:

(a) unallocated water was available after the revised EWP were met;

(b) higher crop water requirements of sugarcane (argued by irrigators as essential) proved to be necessary for economic cane production;

(c) these could be applied without causing excessive groundwater accessions; and

(d) progress had been made on improving distribution and on-farm efficiencies.

[67] Without the EWP constraint, at least 2,100 GL per year could be diverted. This is termed the engineeringly divertible yield (National Water Audit, 2000). This implies that at least 600 GL of water per year is not available for diversion because of the adopted EWP. It does not mean that at least 600 GL of water is released down the river each year.

An allocation of 740 GL was proposed for the M2 Supply Area. In line with the Wesfarmers-Marubeni M2 Supply Area proposal, this would be sufficient to irrigate 32,000 ha of sugarcane assuming on-farm and distribution efficiencies of 80 per cent and 90 per cent respectively. Preliminary designs included on-farm recycling systems and balancing storages within the distribution system, suggesting that these high efficiencies could be achieved.

An allocation of 195 GL/yr was proposed for lower Ord River developments. Approximately 80 per cent of the proposed irrigation areas have sandy loam soils suitable for permanent plantations of citrus varieties and bananas. The allocation made provision for 7,000 ha of such plantations and 1,800 ha of *Leucaena* likely to be grown on the black soils. With the exception of the black soil areas, the downstream developments were expected to be supplied through a piped reticulation system with consequent high levels of distribution and application efficiencies.

For hydro-power generation

The allocation plan also committed to the long term generation of 110 GWhrs/yr of energy from the hydro-electric plant at the Ord River Dam. This represents sufficient power to meet the needs of the East Kimberley electricity grid until beyond the year 2030. Under the existing (1994) Water Supply Agreement (WSA) for the operation of the hydro-power station, a minimum of 210 GWhrs/yr of energy can be generated in years when the water level in Lake Argyle is above 78 m AHD. This is possible only while the irrigation demand is low. When Stage 2 Supply Area projects proceed and irrigation demands increase, releases to meet power demands may not always coincide with irrigation releases. Future power demands on the station were expected to decline when the Argyle Diamond Mine began phasing down its alluvial operations from 2003. The plan indicated that long term contracts that require the generation of more than 110 GWhrs/yr would need to be conditional on generating the additional power at times of irrigation or other releases.

A 2.1.2. Effects of the proposed allocations on the downstream environment

The draft plan acknowledged that changes in flow regime since the 1970s had already impacted the ecology of the riverine system, although the changes were not well documented. Most of the changes were likely to be caused by the reduced flood flows following the construction of the Ord River Dam. However, further changes were expected when Stage 2 Supply Area developments proceeded.

The draft plan described how the post-regulation flow regime downstream of the Kununurra Diversion Dam could be modified by additional abstractions for irrigation. Annual and monthly flows were presented for the current flow situation, proposed full irrigation development and the natural conditions prior to the construction of the dams. Relative to the current situation, annual volumes and variability of flows under the proposed allocations were reduced, this is consistent with the higher irrigation abstractions. Median monthly flows during the dry season would reduce from around 120 GL currently to around 20 GL under the proposed allocations. The river ceased to flow in most dry seasons prior to construction of the dams. River depths were also estimated to reduce from current levels under the full development scenario.

With improved irrigation management in Stage 1 areas (and a consequent reduction in nutrient input to the lower Ord River) and given the potential to use unallocated water for dry season water quality management, the Commission considered the likely environmental effects of the proposed allocations were manageable. The need to revise the interim EWP was highlighted. This would occur when more information on the riverine ecology was available to determine ecological water requirements. The need for adaptive management was reflected in the proposal to issue surface water licences only until the interim allocation plan was updated or for a maximum of five years (whichever was the sooner).

A 2.1.3. Public comments and the Commission's response

Public comments received on the draft were collated and summarised by the EPA and reported in an appendix to the EPA bulletin on the draft plan (EPA, 1999). Comments covered the issues of the precautionary principle and resource security. Some considered that, as little was known about the ecology of the river system, no new allocations should be made at this stage. Others considered that the Commission had not been sufficiently precautionary in its approach. Conversely, one submission considered that the intended licences provided insufficient resource security for new investment in irrigation to proceed. The owners of the ORDHP Station objected to the limited allocation of water for hydro-power generation, indicating that their existing 1994 WSA continued until 2021, unless renegotiated, and included an option for extension. If the demand on the power station remained high when new irrigation areas were established, they would object to any constraints being placed on their ability to generate the minimum of 210 GWhrs/yr of the 1994 WSA.

The methodology used in adopting the interim EWP was criticised. Concerns raised about the proposed allocations included their potential impact on the downstream environment, recreational fishing and tourism and a large scale aquaculture development proposal reliant on diluted seawater from the estuarine portion of the lower Ord River. Current poor water and chemical management in the existing irrigation area and the consequent risk to downriver water quality were raised by a number of submissions. One considered that no further development should take place until improved management was implemented. The lack of consideration of Aboriginal heritage and Native Title issues was also highlighted.

The Commission's response, also included in the EPA bulletin (EPA, 1999), indicated that many of the points made would be addressed before additional irrigation diversions took place. The Commission acknowledged the arbitrary nature of the interim EWP but re-emphasised that they were unlikely to significantly affect the lower Ord River flows prior to the EWP being completely re-assessed when more information on the riverine ecology became available and environmental values could be set. This was expected to occur before current water demands would change significantly. The importance of the interim EWP therefore, was to enable a first estimate of the available water for future irrigation expansion to be made and to establish the principle of making provision for the environment prior to setting consumptive use levels. They were not developed to protect defined downstream environmental values in the short term.

The plan clearly indicated some uncertainty would remain in the water available for irrigation expansion until downstream environmental values were set, a better understanding of the ecological, social and cultural impacts of current and planned water use had developed and such information was included in an updated allocation plan. The response also acknowledged that such information was unlikely to be available before significant investment decisions on further expansion of the irrigated areas were to be made. The response emphasised the Commission's intent to promote an efficient and responsible irrigation industry, and that the interim plan sought to "provide a reasonable estimate of the available water for expansion given the current uncertainties, and be clear that the proposed water allocations cannot be guaranteed without qualification." It went on to say "It is ultimately up to the developers to consider the commercial risks involved in making their final investment decisions. The public review process and the related EPA advice on the draft plan, and the Commission's response in a revised Water Management Plan will help clarify the risks involved."

A2.2. EPA advice on the 1999 draft allocation plan

The EPA completed its review of the May 1999 draft plan and public submissions and published its recommendations as Bulletin No. 965 (EPA, 1999). The EPA concluded "that the basis for determining interim EWP for the Ord River should be reviewed as a matter of priority, before the Interim Water Management Plan is finalised and prior to specific allocations to additional consumptive uses being approved" (EPA, 1999).

The EPA questioned the appropriateness of the 20th percentile monthly flow volume figure, and the application of this figure on pre-dam flows, when the Ord River has been regulated for 30 years. The EPA was concerned that the riverine environment of the lower Ord River had adapted to a fundamentally different flow regime and that partial return to pre-dam flows could generate adverse environmental effects. Changed ecological and new social values associated with the post-regulation flow regime had also developed and their protection should be an important consideration in the review of the EWP.

The EPA also recommended the Commission should "undertake a review of current best practice in defining the EWP for wet-dry tropic rivers." This review was to include "people with expert knowledge of tropical river ecosystems, and the outcome of that review was to be used to define the interim EWP in the Interim Water Allocation Plan."

The EPA supported the Commission intention to undertake additional studies and to review water licences following revision of the Interim Water Allocation Plan.

Appendix 3. Interim EWR and EWP flows for the lower Ord River

A3.1. Introduction

A 3.1.1. Purpose

The purpose of this appendix is to explain the development of the interim EWR and EWP flows outlined in Section 3 and Section 4. It describes the approach used and investigations carried out that underpinned their estimation and adoption by the Commission. The appendix necessarily repeats some information included in Sections 3 and 4.

A 3.1.2. Scope and approach

As recommended by the EPA (EPA, 1999), the Commission established a panel of river ecologists (the Scientific Panel) in 2000 to advise on how best to revise the interim EWR to protect the post-dam riverine environment of the lower Ord River. Given the then limited knowledge of the aquatic environment of the lower Ord, the Scientific Panel proposed a precautionary approach, based on keeping sufficient flows in the river to void major changes in downstream aquatic habitat during each dry season (Section A3.2). The way this approach was applied to establish the interim EWR flow regime of 45-40 m^3/sec for the lower Ord River is described in this appendix (Section A3.3)

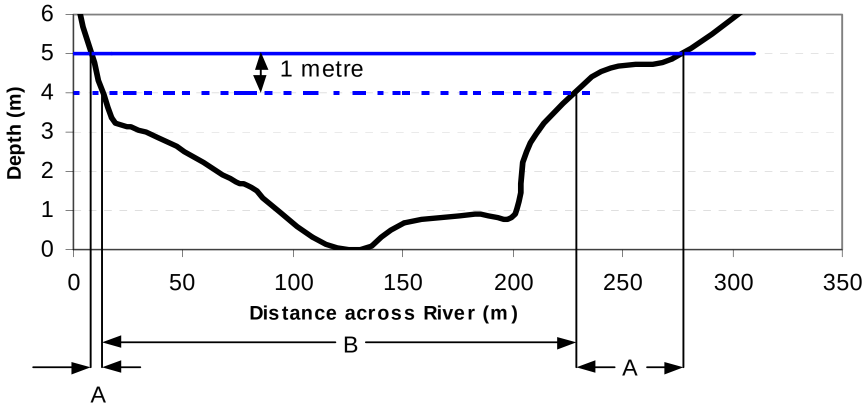
The Commission adopted the interim EWP for the lower Ord River to be the interim EWR in 95 per cent of years. However, as explained in Section 4, in the remaining 5 per cent of years when storage levels in Lake Argyle become critically low, the Commission considered that the EWP flow can be 10 m^3/sec lower, without serious risk to the environment. This approach reduces the severity of water restrictions required to be placed on commercial water use during such drought times. The results of studies carried out to assess the ecological risks of this drought period EWP are also discussed in this appendix (Section A3.3).

A3.2. Interim EWR methodology

As described in Section 3.3 the Scientific Panel identified five environmental attributes important for the continuing biological health of the lower Ord River. Of these, maintenance of in-stream habitats during the dry season was considered the most important attribute to maintain ecological health of the lower Ord River. As explained below, hydraulic modelling techniques enable simple measures of in-stream habitats to be determined at different flow rates and locations along a river reach. For the lower Ord River, an approach was developed based on setting a minimum dry season flow rate that limited the change in the measures of in-stream habitat to an acceptable (low risk) level.

The degree to which this flow rate maintained or protected the other environmental attributes was then evaluated. This simple risk minimisation approach formed the basis of defining the interim EWR for the lower Ord River.

The wetted perimeter of the river channel provided a simple measure of available in-stream habitats for invertebrates and fish. The wetted perimeter is a function of the shape of the river channel and the river flow rate and can be approximated by the river width for broad, relative shallow rivers such as the lower Ord. From river hydraulic modelling, water levels, widths and average water velocities can be calculated for particular flow rates at points along the river where channel cross-section data are available. A wetted perimeter can be derived from these calculations to represent the wetted area per unit width of the channel at each cross-section. The wetted perimeter or area can be partitioned into indices that reflect deep (>1 m) and shallow (<1 m) habitats as shown in Figure A3.1. Changes in these measures of available habitats can be determined for different river reaches and flow rates.



A = Wetted perimeter <1 metre deep

B = Wetted perimeter >1 metre deep

Figure A3.1. Channel cross-section showing how wetted perimeters were estimated

The Department has acknowledged that simple wetted perimeter indices clearly cannot reflect the full complexity of in-stream habitats or the importance of particular local habitats. The partitioning of habitats into shallow and deep zones was based on an assumption that these zones would support different fauna assemblages, rather than a specific understanding of habitat preference. Species diversity, abundance and biomass are dependent on many factors in addition to available habitats. Local heterogeneity of habitats can significantly impact how much of the available habitat is occupied by determining the different aquatic fauna species. Factors such as local depth and flow variability, riparian vegetation and its shading effects, the type and amount of debris within the channel, substrate characteristics, emergent macrophyte growth, and water quality can all be important.

Notwithstanding these limitations, the Scientific Panel considered that using changes in wetted perimeter to reflect in-stream habitat change was an appropriate approach given the level of knowledge about the aquatic ecosystems in the lower Ord River at the time.

A precautionary approach to change was also considered appropriate given the simplifications of the approach and limited level of knowledge. Accordingly, the Scientific

Panel advised that wetted perimeter changes less than 10 per cent were likely to be insignificant; changes of between 10 to 20 per cent of potential concern; and changes greater than 20 per cent would be of considerable concern. The Commission were guided by this advice when applying the risk-minimisation approach outlined above.

A3.3. Application of interim EWR methodology

A 3.3.1. Maintaining in-stream habitat

The interim EWR methodology was initially applied to the lower Ord River in September 2000. This involved the development of the lower Ord River hydraulic model (Mike-11) that enabled indices of wetted perimeter to be calculated for different flow rates in the lower Ord River. The initial calibration was based on 51 channel cross-sections surveyed during June 2000, distributed along the 94 km of river channel from the Kununurra Diversion Dam to where the river becomes fully estuarine at The Rocks (see Figure A3.2).

Wetted perimeter values (and average flow velocities) were calculated at each cross-section for a range of dry season low flow rates. Results were aggregated for three distinct geo-morphologic reaches of the lower Ord River. These were defined as the reach from Kununurra Diversion Dam to Tarrara Bar; from Tarrara Bar to the point where upstream flow first occurs on spring tides (73.1 km below the Kununurra Diversion Dam); and the downstream reach to The Rocks, where tidal influences dominate. The change in the amount of shallow (< 1 m depth) and deep (>1 m depth) water within pools and faster flowing sections of each reach were also determined. The faster flowing sections, termed runs, were defined as those where the average water velocity was greater than 0.3 m^3/sec, and pools defined as those sections where average velocity was less than 0.3 m^3/sec.

Measures of shallow (<1 m depth) and deep (>1 m depth) habitat were calculated for each reach by summing the wetted perimeters for the pools and runs in each reach and weighting them based on the length of each type within the reach[68].

[68] Pools were the dominant river form, being 75 km (80 per cent) of the 94 km from the Kununurra Diversion Dam to The Rocks, with 28 km (85 per cent of the reach total) and 28 km (70 per cent) being pools in the upper two reaches and 19 km (95 per cent) in the tidal reach.

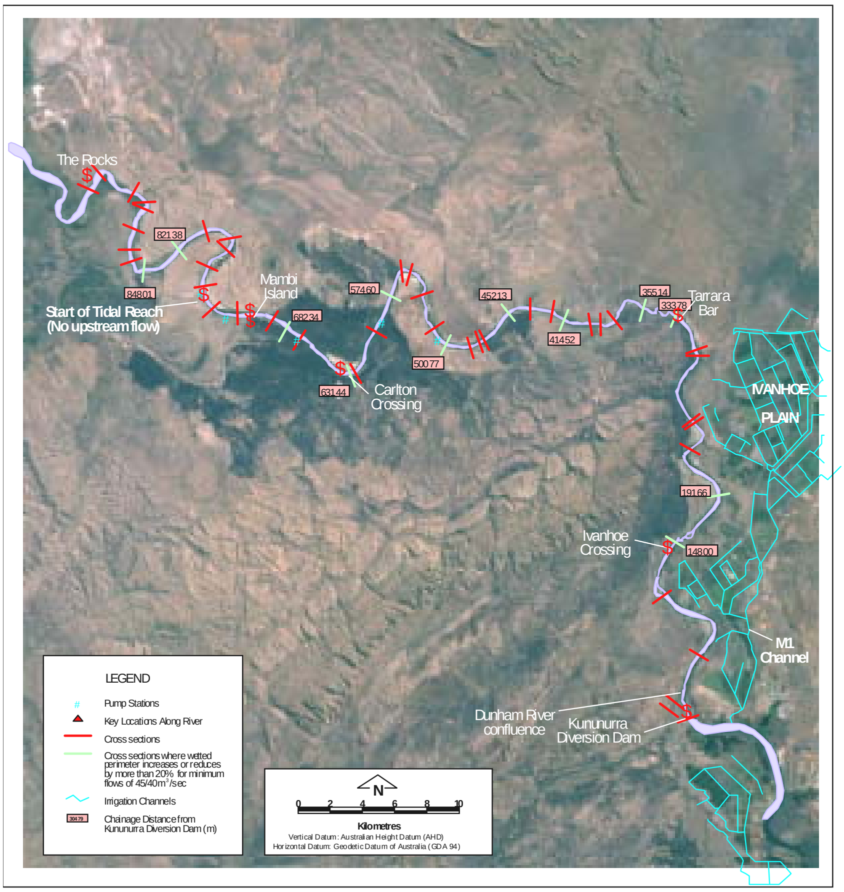


Figure A3.2. Cross-sections used to determine wetted habitat of the lower Ord River

Additional data on channel morphology for the 25 km from Tarrara Bar to Carlton Crossing (in the middle reach) were collected by echo sounding surveys carried out in August and November 2002. In January 2003, an additional 55 cross-sections from these data were used to recalibrate the existing hydraulic model, improving the flow-level definition in the reach where the greatest change in habitat had been previously calculated. Changes in the wetted perimeter values and habitat measures at the original 51 cross-sections were then recalculated, to enable comparison with the previous work.

Wetted perimeter values and shallow and deep habitat measures at particular flow rates were expressed as a percentage of the equivalent wetted perimeter value or habitat measure for the standard flow rate of 50 m^3/sec. This flow rate was adopted as being representative of dry season flow rates in the lower Ord River since the Ord River Dam was constructed. It was calculated as the median of the five month minimum of monthly average flow rates over each dry season between 1974 and 1999 (see Figure A3.3). The five month minimum of average daily flow rates during the dry season was used to exclude months with high flows caused by either a late finish to the previous wet season or an early start to the following wet season.

Figure A3.4 shows the number of cross-sections where the wetted perimeter changed by more than 20 per cent for flow rates between 45 m^3/sec and 30 m^3/sec, relative to the dry season base of 50 m^3/sec. Results are presented for the 2000 and 2003 hydraulic models.

Results from the 2000 hydraulic model were used to develop an interim EWR flow regime based on limiting the number of cases where the change in shallow (<1 m depth) and deep (>1 m depth) wetted perimeter values at the surveyed cross-sections were more than 20 per cent. The number of cases could be limited to less than 15 per cent if flows were maintained at 45 m^3/sec for the first 58 km downstream of the Kununurra Diversion Dam (to House Roof Hill) and 40 m^3/sec further downstream. Figure A3.3 shows the location of cross-sections where changes greater than 20 per cent were calculated.

The January 2003 re-calibration of the hydraulic model significantly reduced the number of cases where the wetted perimeter changes exceeded 20 per cent (see Figure A3.4). Less cases were predicted at 40 m^3/sec than predicted at 45 m^3/sec using the initial calibration, and, under the proposed interim EWR, the number halved from 14 per cent to 7 per cent of cases.

Table A3.1 presents the changes in shallow and deep habitat for the three river reaches, based on the re-calibrated hydraulic model. The total of shallow and deep habitats and the deep water habitat (>1 m depth) decreases as the flow rate decreases. This occurs in both pools and faster flowing sections (runs) of all three river reaches (see Table A3.1). Shallow water habitats, however, increase in some cases and decrease in others, depending on the river reach and flow rate[69]. Under the proposed interim EWR regime, the changes in river reach habitats were all limited to 18.2 per cent or less. The greatest reduction occurs in the deeper water (> 1 m depth) of the faster flowing sections (runs) in the reach between the Kununurra Diversion Dam and Tarrara Bar, where the habitat is expected to reduce to 89.9 per cent of the habitat present at a flow rate of 50 m^3/sec.

The re-calibration suggested that the initial EWR, based on 45 m^3/sec to House Roof Hill, was conservative and that flows of 40 m^3/sec in this reach could be acceptable. However, since the mid 1990s dry season flow rates have increased in response to growing hydro-power demand and are now consistently higher. Dry season flow rates unaffected by contributions from Lake Argyle spillage were typically 60 m^3/sec by the end of the decade, and in recent years have exceeded 70 m^3/sec.

The aquatic fauna and flora of the lower Ord River can be expected to adapt to these higher flows given sufficient time. Under a scenario of continued high power demand for several more years with no new irrigation demand, followed by rapid development of new irrigation areas, the aquatic habitat changes of Table A3.1 may be underestimates. To consider possible habitat changes under this scenario, the aquatic habitats expected for the interim EWR regime of 45-40 m^3/sec were compared with habitats expected under a higher dry season flow rate of 60 m^3/sec. The results are presented in Table A3.2.

69 An increase in shallow habitat (<1 m depth) can occur where the river bed has an extensive flat section or bench, and the depth of water above the bed or bench reduces from greater than one metre to less than one metre.

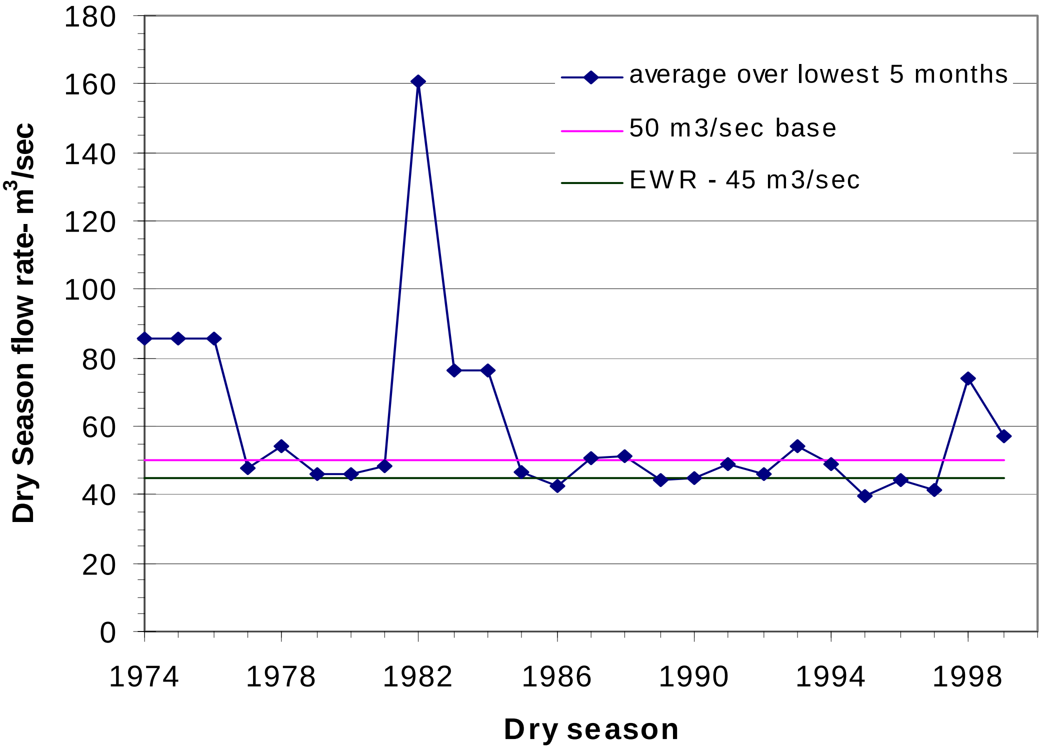


Figure A3.3. Dry season flow rates in the lower Ord River d/stream of the Dunham River

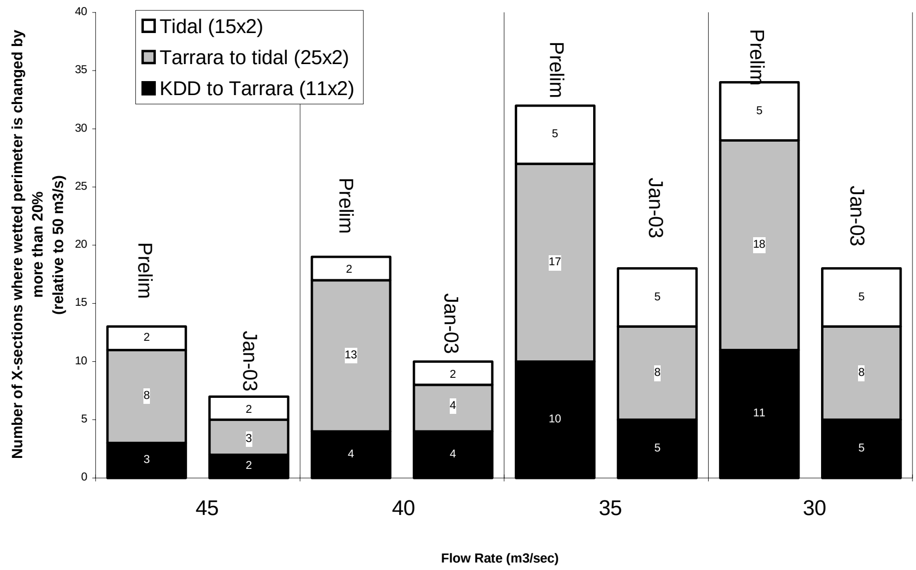


Figure A3.4. No. of wetted perimeter changes that exceed 20 per cent from 50 m^3/sec to 45,40,35 and 30 m^3/sec –based on hydraulic modelling calibrated in 2001(preliminary) and re-calibrated in January 2003

Table A3.1 Effect of flow rate on shallow and deep water habitats- Base: 50 m^3/sec

Each habitat measure is expressed as a per cent change from the habitat present at flow rate of 50 m^3/sec
(Values that change by >20 per cent are highlighted in bold. Bracketed values are for the 2000 calibration)

A: Total

Lower Ord River flow regime	45 m^3/sec	45-40 m^3/sec[‡]	40-35 m^3/sec[‡]	35-30 m^3/sec[‡]	30 m^3/sec
River reach					
Diversion Dam to Tarrara Bar (11)					
Shallow (depth <1 m)	100.3	100.3 (98.8)	97.5	95.3	94.7
Deep (depth >1 m)	97.4	97.4 (95.8)	95.1	93.2	91.2
Tarrara Bar to Tidal Reach (25)					
Shallow (depth <1 m)	100.2	100.1 (106.5)	98.4	93.0	91.1
Deep (depth >1 m)	98.0	97.5 (92.2)	95.8	94.4	90.0
Tidal Affected Reach (15)					
Shallow (depth <1 m)	104.0	109.0 (108.0)	111.3	115.4	115.4
Deep (depth >1 m)	99	98.2 (98.3)	97.4	96.4	96.4

B: Pools

River reach					
Diversion Dam to Tarrara Bar (11)					
Shallow (depth <1 m)	100.6	100.6 (99.2)	98.1	95.9	94.5
Deep (depth >1 m)	98.9	98.9 (97.2)	97.5	96.5	95.4
Tarrara Bar to Tidal Reach (25)					
Shallow (depth <1 m)	98.8	97.9 (95.2)	97.2	91.2	88.4
Deep (depth >1 m)	99.4	99.3 (98.1)	98.4	97.6	92.0
Tidal Affected Reach (15)					
Shallow (depth <1 m)	108.8	118.2 (116.6)	**125.2**	**134.9**	**134.9**
Deep (depth >1 m)	98.7	97.5 (97.7)	96.5	95.3	95.3

C: Runs

River reach					
Diversion Dam to Tarrara Bar (11)					
Shallow (depth <1 m)	98.6	98.6 (96.2)	94.2	91.8	88.7
Deep (depth >1 m)	89.9	89.9 (88.0)	81.5	**74.5**	**68.0**
Tarrara Bar to Tidal Reach (25)					
Shallow (depth <1 m)	103.5	103.7 (**132.9**)	101.0	97.2	97.2
Deep (depth >1 m)	94.7	93.5 (**78.6**)	89.8	86.9	88.5
Tidal Affected Reach (15)					
Shallow (depth <1 m)	102	103.6 (103.5)	104.7	107.4	107.4
Deep (depth >1 m)	97.8	96.1 (96.2)	94.0	90.6	90.6

‡ The higher flow rate is maintained till House Roof Hill (i.e. for the first 58 km downstream of the Diversion Dam)
† Sections where average velocity is > 0.3 m/sec

Table A3. 2 Effect of flow rate on shallow and deep water habitats- Base: 60 m^3/sec

Each habitat measure is expressed as a % change from the habitat measure at a base rate of 60 m^3/sec (Values that change by >20 per cent are highlighted in bold)

A: Total

Lower Ord River flow regime	45 m^3/sec	45-40 m^3/sec‡	40-35 m^3/sec	35-30 m^3/sec	30 m^3/sec
River reach					
Diversion Dam to Tarrara Bar (11)					
Shallow (depth <1 m)	96.0	96.0	93.4	91.3	89.9
Deep (depth >1 m)	86.6	86.6	84.9	83.7	82.2
Tarrara Bar to Tidal Reach (25)					
Shallow (depth <1 m)	99.4	100.4	97.6	92.3	90.4
Deep (depth >1 m)	96.3	95.9	94.2	92.8	88.5
Tidal Affected Reach (15)					
Shallow (depth <1 m)	**66.2**	**70.0**	**72.7**	**76.5**	**76.5**
Deep (depth >1 m)	99.4	98.5	97.7	96.8	96.8

B: Pools

Lower Ord River flow regime	45 m^3/sec	45-40 m^3/sec‡	40-35 m^3/sec	35-30 m^3/sec	30 m^3/sec
River reach					
Diversion Dam to Tarrara Bar (11)					
Shallow (depth <1 m)	101.0	101.0	98.4	96.3	94.9
Deep (depth >1 m)	93.9	93.9	92.7	91.8	90.7
Tarrara Bar to Tidal Reach (25)					
Shallow (depth <1 m)	97.2	96.9	95.7	89.7	87.0
Deep (depth >1 m)	98.7	98.5	97.7	96.9	91.3
Tidal Affected Reach (15)					
Shallow (depth <1 m)	**71.8**	**78.1**	82.7	89.1	89.1
Deep (depth >1 m)	99.8	98.6	97.6	96.3	96.3

C: Runs

Lower Ord River flow regime	45 m^3/sec	45-40 m^3/sec‡	40-35 m^3/sec	35-30 m^3/sec	30 m^3/sec
River reach					
Diversion Dam to Tarrara Bar (11)					
Shallow (depth <1 m)	**68.0**	**68.0**	**65.0**	**63.3**	**61.2**
Deep (depth >1 m)	**45.2**	**45.2**	**40.9**	**37.4**	**34.1**
Tarrara Bar to Tidal Reach (25)					
Shallow (depth <1 m)	101.0	104.9	95.7	98.3	89.1
Deep (depth >1 m)	90.8	89.7	86.2	83.3	82.0
Tidal Affected Reach (15)					
Shallow (depth <1 m)	117.5	119.4	**120.7**	**123.8**	**123.8**
Deep (depth >1 m)	89.8	88.3	86.3	83.2	83.2

‡ The higher flow rate is maintained till House Roof Hill (i.e. for the first 58 km downstream of the Diversion Dam)
† Sections where average velocity is > 0.3 m/sec

As expected, the flow regime changes relative to this higher base were greater. However, changes remained less than 11.7 per cent in all but two cases. The two cases of larger change again occurred in the faster flowing sections of the reach from Kununurra Diversion Dam to Tarrara Bar. Under the proposed EWR regime, the shallow water habitat would be 45 per cent, and the deeper water habitat 68 per cent of the respective habitats at 60 m^3/sec. While these changes are greater than 20 per cent, they are not considered to be of considerable concern to the invertebrate and fish species of the lower Ord River for the following reasons. The river pools, which occupy 75 km or 80 per cent of the lower Ord River and provide most of the habitats for aquatic fauna, are not changed significantly. In addition, the faster flowing habitats in the lower two reaches of the river are also not changed significantly. These occupy approximately 12 km of the river and represent about two and a half times the length of the upper reach (approximately 5 km) where the greatest changes are expected. Given the limited extent of these largest habitat changes, the mobility of aquatic fauna, and the capacity of aquatic flora to respond to change, the change in dry season flow regime envisaged under the scenario described, should not place the aquatic species of the lower Ord River at any significant level of risk.

A 3.3.2. Maintaining water quality

The biological health of the lower Ord River is also critically dependent on its water quality. Although Stage 1 areas contribute additional nutrients to the lower Ord River, the historic dry season flows of the lower Ord River have supplied sufficient dissolved oxygen input to ensure the river pools have remained well oxygenated. The Scientific Panel were concerned that a significant reduction in dry season flow rates would reduce the supply of oxygen. Under adverse meteorological conditions and high levels of biological oxygen demand, dissolved oxygen levels in deeper pool water could decline and lead to an increased risk of de-oxygenation in extreme cases, with undesirable environmental impacts.

While cognisant of the Scientific Panel's concerns, consideration was given in determining whether a reduction in the lower Ord River flow rate from 45-35 m^3/sec in the reach to House Roof Hill, would be acceptable in 5 per cent of years when Lake Argyle storage levels were very low. If the interim EWR of 45 m^3/sec were maintained during these times, severe restrictions on irrigation and hydro-power releases would be necessary to ensure that the minimum operating level of Lake Argyle was not exceeded and to provide emergency water for the following year if the drought persists (see Section 4.4 for details).

A low flow field trial and dissolved oxygen modelling study was carried out to assess the risk to the lower Ord River environment of reducing the proposed EWR during drought periods. The field trial was conducted in October 2002 focusing on two pools in the reach between Tarrara Bar and Carlton Crossing. The trial involved detailed monitoring of pool hydrodynamics and aquatic fauna and flora responses under three flow conditions:

- an initial flow period (approximately 90 m^3/sec);
- a low-flow period (31 m^3/sec); and
- post low-flow period (approximately 90 m^3/sec).

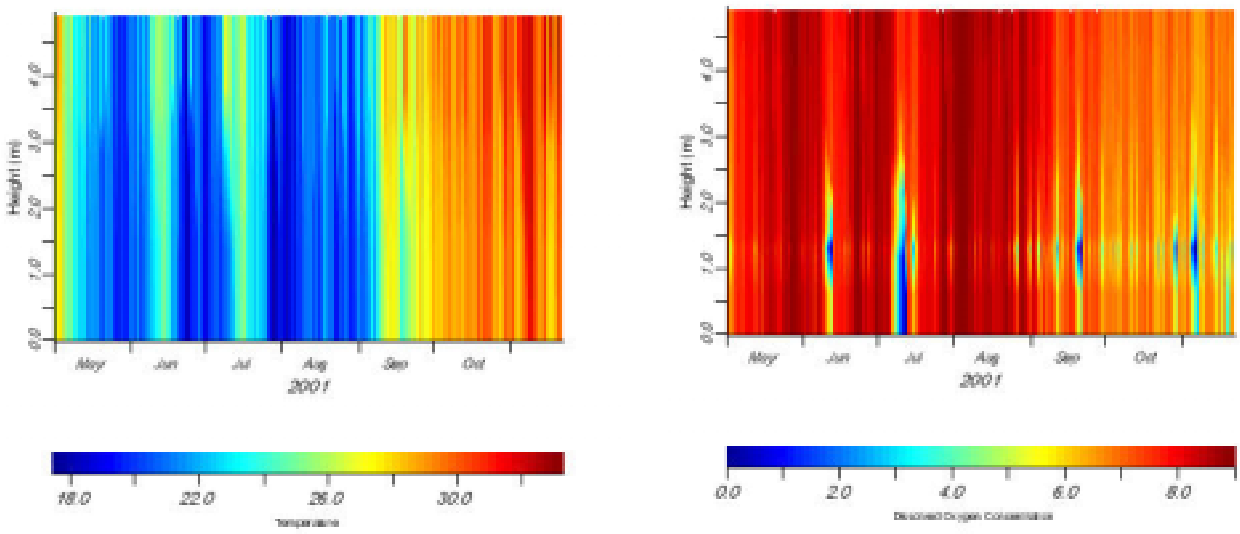
Each flow condition was maintained for approximately two days and a further day taken for the flows to reduce to 31 m^3/sec and to recover to 90 m^3/sec. Data on local meteorologic conditions, pool stratification, oxygen dynamics, changes in habitat and aquatic fauna responses were recorded over the eight days of the trial. The understanding of pool hydrodynamics gained from the trial was then used to model dissolved oxygen concentrations in Carlton Crossing pool over an extended dry season and under more extreme climatic and biological loading conditions.

Oxygen dynamics in river pools

The field trial and modelling study indicated that dissolved oxygen (DO) concentrations were strongly influenced by local meteorologic conditions (mainly wind strength, thermal stratification during the day and cooling from the surface at night) and not strongly affected by flow rate, at current biological loadings. Some reductions in DO concentrations were observed at low flows during the field trial. These occurred when thermal stratification developed during the day when the flow was reduced to 31 m^3/sec but was broken down by either wind mixing or night cooling by mid evening on each of the three days of low flow. DO concentrations reduced to 5.5 mg/L (70 per cent of saturation) at depth in Carlton Crossing pool at times of stratification but became re-oxygenated (100 per cent saturated) by mid evening when the thermal stratification broke down.

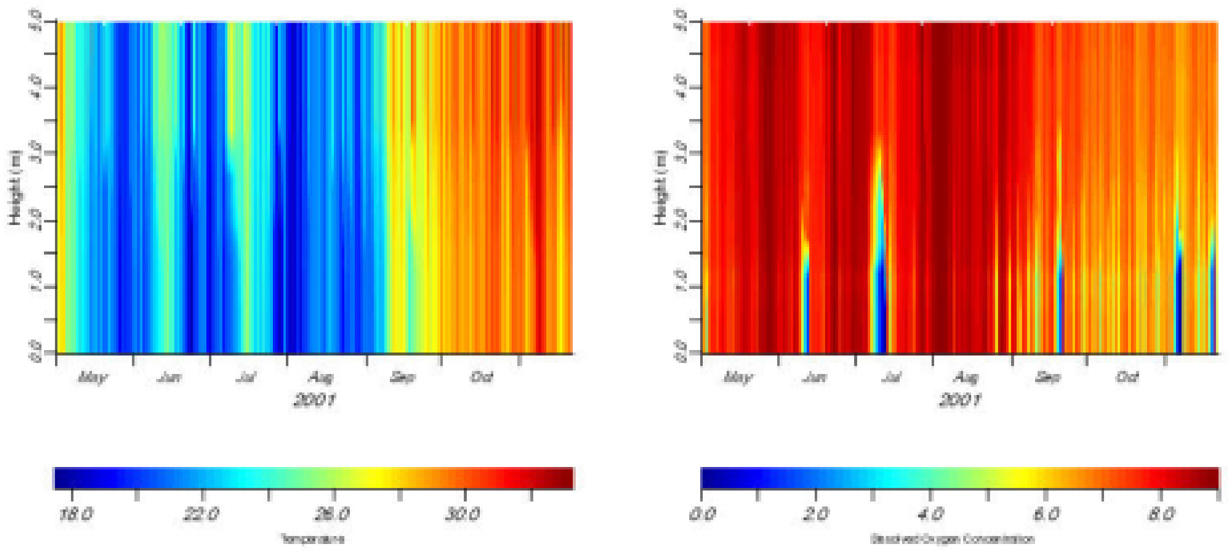
The extended dry season modelling indicated that, in pools like Carlton Crossing pool, prolonged periods of low wind speed (<3 m/sec at 10 m AHD) can result in thermal stratification persisting for four consecutive days and cause DO levels to decline to 2 mg/L at depth (see Figure A3.5; Trayler *et al.,* 2006). The top 2.5 m remained above 5.0 mg/L throughout (approximately 50 per cent of saturation at July temperatures). Hence, while the aquatic fauna would be under stress at these times of adverse meteorological conditions, significant DO would remain available to aquatic fauna in the upper part of pools along the lower Ord River. Importantly, similar levels of DO depletion were predicted at flow rates of 45 and 65 m^3/sec under the same meteorological conditions (compare Figure A3.6 with Figure A3.5). That is, at current levels of biological loading, and for the rates studied, flow rate was not a major factor in affecting dissolved oxygen concentrations in river pools. Limitations in the modelling were apparent, especially those stemming from the simplification of daily inflow and outflow calculations. As the nominal retention time for water in Crossing pool was 12 hours at 35 m^3/sec (Trayler *et al.,* 2006), mixing effects due to the continuous inflow and outflow were probably underestimated in the modelling. The predicted declines in DO under adverse meteorological conditions were therefore likely to be overestimated.

A sensitivity analysis indicated that river flow rate only influenced dissolved oxygen concentrations of pool water when the biological oxygen demand within the pool was doubled, or the oxygen saturation level of pool inflow water was reduced from 100 per cent to 70 per cent. The effect of a flow rate reduction from 45 m^3/sec to 35 m^3/sec remained small, relative to wind and thermal stratification effects and larger flow rate changes (90 to 45 m^3/sec). Stage 1 irrigators are required to significantly improve their irrigation efficiencies and reduce the nutrient input to the lower Ord River by 2008. In addition, during drought periods when the environmental flow reduction may apply, greater reductions in irrigation return flows can be expected. At these times of water restriction, water is in short supply and irrigators make extra effort to minimise their water wastage. Hence the changes used in the sensitivity analysis (doubling of pool biological oxygen demand and lower incoming oxygen saturation levels) are not expected to occur in the future.



(a) Temperature (b) Dissolved oxygen

Figure A3.5. Temperature (°C) and DO predictions in Carlton Crossing pool- 35 m³/sec
Scenario13: For a constant inflow of 35 m3/sec, average biological water quality conditions as observed from 18-24 October 2002 and meteorological data from May-November 2001 at the Agriculture WA Mantinea-Ord Meteorological Station.



(a) Temperature (b) Dissolved oxygen

Figure A3.6. Temperature (°C) and DO predictions in Carlton Crossing pool- 45 m³/sec

Scenario14: For a constant inflow of 45 m³/sec, average biological water quality conditions as observed from 18-24 October 2002 and meteorological data from May-November 2001 at the Agriculture WA Mantinea-Ord Meteorological Station.

Aquatic fauna responses during the low flow field trial

Monitoring aquatic fauna responses to flow changes during the low flow field trial centred on pools, shallow backwaters and submerged macrophyte bed habitats. These were considered the most critical to fish populations (i.e. supported highest diversity and abundance) and had the highest likelihood of being affected by changes in river flow. Little change occurred in fish biomass, species richness and abundance in pools sampled during or after the low flow period[70] (see Figure A3.7) This was expected given the relatively small changes in pool water depth caused by the flow reduction. These were no more than 0.5 m and typically less than 12 per cent of the pool depth.

However, larger water level reductions (up to 1.2 m) occurred in macrophyte beds and backwaters, resulting in significant reductions in the physical extent of these localised habitats[71] (see Plates 1-3). Two types of backwater habitats were affected: larger backwaters parallel to the main channel (Plate 2) and smaller flooded mouths of small tributaries that enter the main channel (Plate 3).

70 Only one individual species Bony Bream (*Nematalosa erebi*) showed significantly lower abundance during the period of low flow.

71 The flow reduction to 31 m³/sec resulted in over 80 per cent of the initial area of submerged macrophyte beds either floating on the water surface or being deposited on areas of exposed river bed, and an approximate 80 per cent reduction in the wetted cross-sectional area of backwater habitats. Small tributary backwaters, which extended from tens to hundreds of metres up the tributary, were typically cut off from the main channel by small sand bars that had formed at the tributary's mouth. These form towards the end of the wet season as high flows in the main channel decline and deposit the sand, and no subsequent local flow in the tributary is sufficient to erode the sand bank.

Freshwater prawns (*Macrobrachium* spp.) were the aquatic fauna most affected in these habitats. The abundance and bio-mass of these invertebrates in macrophyte beds declined very significantly during the low flow period (31 m^3/sec) and did not recover in the two days after the flow returned to pre-reduction rates (approximately 90 m^3/sec) (see Figure A3.8).

The effect on fish was smaller, with most changes in abundance, bio-mass and species richness not being significant. [72] However, fish bio-mass caught in backwaters and macrophyte beds declined during and after the low flow period [73] (see Figure A3.8).

Macrophyte beds are the preferred habitats for several small species of fish (i.e. Mouth Almighty (*Glossamia aprion*) and Empire Gudgeon (*Hypseletris compressa)*) and for immature and smaller species of freshwater prawns (*Macrobrachium* spp*.)* (Storey, 2003; Trayler *et al*., 2006) .These prawn species, used as bait by recreational fishers to catch Barramundi (*Lates calcarifer*) in the lower Ord River, have been shown to be extremely important in the diet of comparable species of fish in the Fly River in Papua New Guinea (Storey *et al.,* 2001), and are therefore considered an important component of the lower Ord's food web.

72 Statistically significant increases occurred in species richness and three individual species Barred Grunter (*Amniataba percoides*), Mouth Almighty (*Glossamia aprion*) and Empire Gudgeon (*Hypseletris compressa*) in macrophyte bed habitats during the low flow period. This habitat is preferred by small species such as the Mouth Almighty (Glossamia aprion) and Empire Gudgeon (*Hypseletris compressa*) and the increased catch is considered a result of their increased density within the remaining areas of their preferred habitat.

73 Catch variability and limited sample size meant that some apparent reductions were not significant at the 5 per cent level.

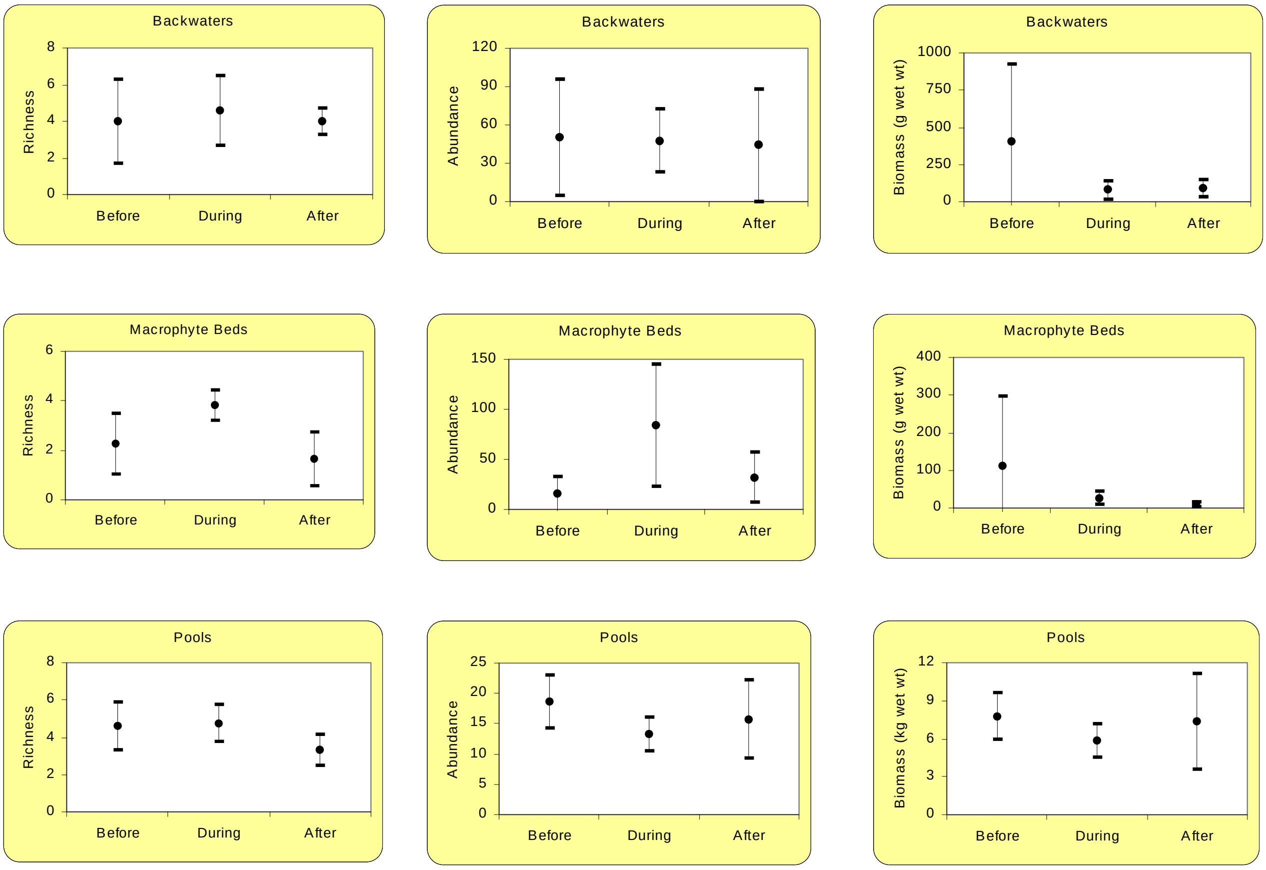


Figure A3.7. Changes in mean (± 95 per cent CI) richness, abundance and biomass of fish in macrophyte beds, backwaters and pools before, during and after the flow rate was reduced to 31 m^3/sec

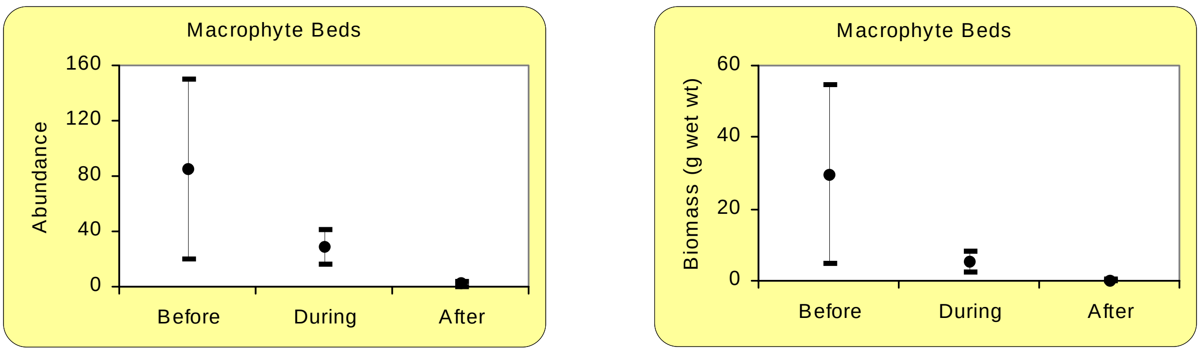


Figure A3.8. Changes in mean (± 95 per cent CI) abundance and biomass of Macrobrachium prawns in macrophyte beds before, during and after the flow rate was reduced to 31 m^3/sec

Plate 1 Shallow backwater before (left) and during (right) the low flow period showing the extent of drying-out

Plate 2 A medium-depth backwater before (left) and during (right) the low flow period showing extent of drying-out.

Plate 3: The mouth of two creeks before (top, left & right) and during (bottom left & right) the low flow period, showing loss of connectivity with the main channel

Backwaters are the preferred habitat for many small bodied species of fish (i.e. Mueller's Glassfish (*Ambassis mulleri*), Australian Rainbowfish (*Melanotaenia splendida australis*)) and for juvenile stages of larger species (i.e. Bony bream (*Nematalosa erebi*), Mullet (*Liza alata*)), providing shallow habitat where they can avoid larger, deeper bodied predators (Storey, 2003). The loss of this habitat would increase predatory pressure on individuals displaced into deeper water, with likely flow-on effects to the population size of small-bodied species, and cohort strength of young-of-the-year juveniles of larger species, leading to population size impacts when this cohort reaches maturity.

Implications of the results of the low flow trial for setting interim EWP

The rate of reduction in flow and water levels applied during the low flow trial were substantially greater than those that usually occur during the dry season. These were imposed so that pool stratification and oxygen dynamics could be monitored under the required range of flow conditions within a short study period. As noted in Section A 3.3.2, flows during the trial reduced from approximately 90 to 30 m^3/sec (within 5 minutes at the Diversion Dam and 18-24 hours at Carlton Crossing pool (see Figure A3.9)). Under the drought period EWP, flows would reduce from 45 m^3/sec to 35 m^3/sec and can readily be introduced at natural recession rates as discussed below. Consequently, the short term impacts on aquatic biota of introducing a drought period EWP are likely to be significantly less than observed during the trial. Reasons for this are elaborated below.

To place the observed trial changes in a longer term context, changes in channel geomorphology and the extent of macrophyte bed habitat, observed since the late 1990s, are described and related to the river's flow regime over this period. Estimates of the daily flows of the lower Ord River at Tarrara Bar for the water years 1998-99 to 2003-04 are shown in Figure A3.9. Also shown are the spillway flows from Lake Argyle, and as an inset, the flow rates during the low flow trial.

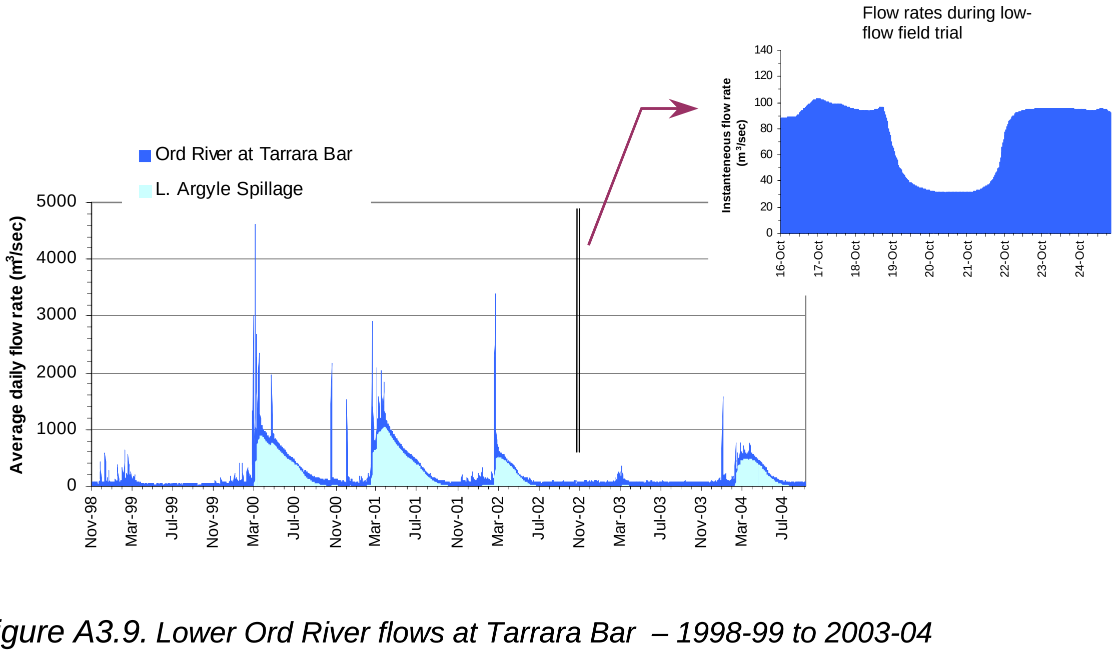


Figure A3.9. Lower Ord River flows at Tarrara Bar – 1998-99 to 2003-04

Figure A3.9 shows that, in wet seasons, the volume of lower Ord River flow is governed by the amount of spillage from Lake Argyle, while flood peaks are governed by the runoff from storm events that occur over the catchment below the Ord River Dam.

Prior to the wet season of 1999-2000 no large floods had occurred on the lower Ord River since 1972 when the Ord River Dam was completed, although high flows had occurred in 1979 and 1982. Since 1982, and possibly earlier, extensive macrophyte beds had developed along much of the lower Ord River. The March 2000 flood washed all macrophyte beds (and the fine silt accumulations, which tend to support the macrophyte beds) from the river system, dramatically reducing the area of this habitat. During the remainder of 2000-01 and early 2002 there was little macrophyte present, with successive large wet season flows in early 2001 and especially the February 2002 flood appearing to restrict re-colonisation. It was not until late 2002 that extensive areas of ribbon weed (*Vallisnaria americanum*) started to re-establish.

This temporal sequence indicates the dynamic nature of the macrophyte bed habitat, and that large floods on the Dunham River tributary have sufficient energy to scour extensive areas of these beds from the lower Ord River. Depending on the magnitude and sequence of such events, it can take several years for the macrophyte beds to re-colonise. Anecdotal evidence from people fishing the lower Ord River suggested that catches of bait fish were limited during the 2002 dry season. This is consistent with the loss of macrophyte bed habitat following the high flow events in the three previous wet seasons and supports the contention that there was an associated reduction in the river's carrying capacity for small fish species (WRC, 2003).

While macrophyte beds are scoured out by major floods, this is unlikely to occur in the wet seasons that precede the introduction of the drought period EWP. Ord River Dam inflows must be well below average for at least two or three wet seasons before Lake Argyle levels drop sufficiently to trigger the 35 m^3/sec drought period EWP. As major flooding is unlikely to occur in the lower Ord River when inflows to the Ord River Dam are well below average, macrophyte beds would have at least two years of undistributed growth (no scouring out), prior to any drought period EWP. Consequently, to avoid the rapid exposure of the macrophyte beds, as occurred in the low flow trial, flows in the lower Ord River would only be allowed to decline at natural recession rates when the drought period EWP is introduced. Change in flow depths over this flow range average less than 0.1 m and no change exceeded 0.28 m at the 51 cross-sections used to determine available habitat change. As part of establishing comprehensive EWR for the lower Ord River, a rate of change in flow from one dry season to the next is being develop to further protect macrophyte bed habitats (Braimbridge and Malseed, in prep.) from excessive change.

Of the two functional habitat types affected during the low flow trial, the loss of side tributary backwaters was considered primarily a result of the trial and the prevailing conditions in 2002, rather than reflecting the likely impact of a drought period EWP.

The loose river bed sands that formed barriers across the small tributaries along the lower Ord River in 2002 are less likely to form in years when there is no spillage from Lake Argyle. Wet season flow events with peaks in excess of 200 m^3/sec have just sufficient power to mobilise and re-distribute loose river bed sands locally. The sands are deposited some distance downstream, as river velocities decrease with the receding flow. Most deposition occurs as flow reduces through the range of approximately 150 to 80 m^3/sec, depending on local channel velocities and the size of the sand particles. Flows of this magnitude in the main channel persisted well into the 2002 dry season, as a result of spillway flows from Lake Argyle (see Figure A3.9). Consequently, sands would have been deposited across the mouths of small tributaries (Plate 3) well after the last wet season rains and local flows would have occurred. Late local wet season rains are much more likely to cause tributary flows to scour out their entry to the main channel in years when there is no spillage from Lake Argyle. As noted above, spillage will not occur in years when the drought period EWP would be applied. In cases where sediments remain across tributaries when the drought period EWP is introduced, the changes to tributary backwater habitats will be much smaller (given the smaller change in flow from 45 to 35 m^3/sec, rather than approximately 80-90 to 30 m^3/sec).

Observations during the trial indicated that the larger main channel backwaters (Plate 2), present at approximately 80-90 m^3/sec, were not replaced by similar backwater habitats at the low flow rate (31 m^3/sec) as had been expected. Although some local redistribution of loose sands occurs in most wet seasons, the main channel backwaters do not appear to change greatly between years, except after large flooding, common before regulation. Based on the observations during the low flow trial, a progressive reduction in this type of backwater habitat would be expected as dry season flow rates reduce through the range 80 m^3/sec-30 m^3/sec. The Department is currently qualifying the relationship between main channel backwater habitat and dry season flow rate as part of developing comprehensive EWR assessments for the lower Ord (Braimbridge and Malseed, in prep.).

While some reduction in main channel backwaters is expected under the interim EWR of 45-40 m^3/sec flow regime, and a further reduction expected in 5 per cent of years when the 35-30 m^3/sec flow regime applies, the ecological impacts are considered small and manageable. Species richness, abundance and biomass of fish communities in the lower Ord River are similar to the unregulated Keep, Dunham and Pentecost Rivers (Trayler *et al.,* 2006). The lower Ord River supports smaller fish species and juveniles of larger estuarine species, and greater fish size was sampled overall. This was considered a consequence of the greater habitat diversity and deeper water in the dry season of the lower Ord River, decreasing predation and competition pressure, and allowing fish to live longer. Relative to unregulated rivers of the region, substantial areas of dry season habitat will be maintained under the interim drought period EWP of 35-30 m^3/sec. Given that some habitats will decrease during the drought period, increased predator pressure is likely and will probably lead to a reduction in the numbers of small species and juveniles of larger species present at the end of the drought period. However, given that the drought interim EWP expect to only occur in 5 per cent of years, the long term implications to fish population structure are likely to be minimal.

Appendix 4. Community consultation

A4.1. Introduction

This appendix describes the community consultation carried out during 2000 that informed the revision of the 1999 Water Allocation Plan. The main outcomes are detailed in Appendix 5 and summarised in the main text of the plan (Section 4). In addition to the community consultation process described here, extensive consultation and negotiation with the prospective water licence holders also occurred. Follow-up discussions with traditional owners have also occurred in relation to waterway management issues and establishing the cultural values study in preparation for the review of this Interim Plan.

A4.2. Community Reference Panel

The EPA report and the public submissions raised several issues to be addressed through revision of the interim EWP. Most of these related to the impacts of full Stage 2 Supply Area irrigation development on the availability of water to meet other social and economic values, including the protection of Indigenous cultural values, recreational fishing, aquaculture and river-based tourism. Because of the number of consultative processes which had already occurred in the Ord River area and the time pressures on the review of the Interim Plan, a limited consultative process was used. This comprised:

- production of a background paper identifying social/other values and management objectives already identified through Kununurra-Wyndham Area Development Strategy (KWADS), Lower Ord Management Plan, Lower Ord Ramsar Site Draft Management Report, Land and Water Management Plan Status Reports, public submissions on the Draft Interim Water Allocation Plan and public consultation for the Kimberley Regional Allocation Plan. Distribution of the background paper and an overview of the EWP process to identified community representatives;
- a series of evening meetings prior to the workshop to familiarise community participants with the process;
- a one day workshop to confirm management objectives and/or scenarios; determine the impacts of the interim EWR on the ability to meet other objectives; identify conflicts between objectives and the flows required to meet them; and propose alternative flow regimes to meet management scenarios (held on 17 June 2000); and
- additional hydrologic modelling as required to identify implications of flow regime options on environmental, social and economic objectives.

A 4.2.1. Reference panel terms of reference

The Community Reference Panel was convened to provide advice to the Commission. Its role was identified as advisory rather than decision-making. It was asked to:

- confirm the range of issues to be considered in determining the interim EWP (based on output from previous consultation and planning processes);
- recommend key social values to be maintained in the Interim Water Management Plan period;
- consider the impacts of the recommended interim EWR on the social values identified;
- develop potential flow scenarios (in terms of heights, frequency and duration of minimum and maximum flows at designated points in river reaches) to accommodate social values; and
- contribute to the development of a communication and participation process for the allocation planning process subsequent to the Interim Water Management Plan.

The group was not required to give a consensus view.

A 4.2.2. Panel representation

A number of community-based groups have already been formed in the Kununurra area in response to other planning and consultation processes, or through community responses to land and water management issues. The Community Reference Group drew upon representatives from these existing groups and included representation from local government, the Aboriginal community, and tourism and recreation interests.

Representatives from the following organisations were invited to participate:

- Shire of Wyndham East Kimberley;
- Lower Ord Community Advisory Committee;
- Ord Irrigation Co-operative;
- Kimberley Land Council;
- Balanggarra Aboriginal Corporation;
- Ord River Irrigation Area Land Conservation District Committee;
- East Kimberley Halls Creek Land Conservation District Committee;
- Land and Water Management Plan Steering Committee;
- Land and Water Management Plan River Group;
- Land and Water Management Plan Conservation Group;
- Land and Water Management Plan Town Group;
- Land and Water Management Plan Land Group;
- Care of the Ord Valley Environment (conservation group);
- Conservation Council of Western Australia;
- Kununurra Tourist Bureau and Kimberley Tourist Association;

- Tourist operators;
- East Kimberley Recreational Fishing Advisory Committee;
- Department of Environment and Conservation (DEC);
- Agriculture Western Australia (Agriculture WA);
- Fisheries Western Australia (Fisheries WA);
- Water Corporation;
- Wesfarmers;
- Kimberley Development Commission; and
- Ord Development Corporation.

Preparation for the community workshop began shortly after the EPA response to the draft Interim Allocation Plan was released (May 1999). As part of the planning process terms of reference for the panel were prepared and presented to EPA, DEP, Environmental Australia and DRD. Key community stakeholders were consulted regarding the changes to the process and to provide advice on the composition of the Community Reference Panel.

Community Reference Panel participants were invited to be apart of the panel on the basis of them being key representatives of various relevant interests, and having prior involvement in community processes or groups where some of the issues have been discussed from a range of perspectives. Thus they were felt to represent both specific interests and the broader community interest. A fairly large number of stakeholders (35) were invited to be on the panel to ensure wide community input and to establish a consultative style to further future negotiations regarding the allocation plan, as well as other water resource management initiatives. The invitation list was eventually more extensive than proposed in the original terms of reference because of the strong interest shown by the community.

Despite the limited consultation process, the Commission aimed to enable effective community stakeholder participation in the EWP process. To this end, representatives were provided with background information to clarify issues relevant to the EWP process and to explain the process. To prepare participants for the workshop they were invited to attend one of three evening meetings. At these meetings, the context for community involvement and the workshop process were explained. The approach to the workshop was to add further information to the Scientific Panel report on the EWR, and facilitate both qualitative and quantitative discussion based around simple models of river cross-sections to generate community values for an EWP. The participants that attended are listed in Table A4.1.

Table A4.1 Panel participants -17 June 2000

Name	Organisation	Position
Peter McCosker	Ord Development Corporation	Ord Project Coordinator
Elaine Gardiner	Ord Irrigation Co-operative	Chairperson
Andrew Kelly	Ord Irrigation Co-operative	Manager
Spike Dessert	Ord Irrigation Co-operative Shire of Wyndham East Kimberley Ord Land and Water Management Plan Land Group	Board Member Councillor Member
Wilhelm Bloecker	Ord Land and Water Management Plan Land Group	Chairperson
Dick Pasfield	Ord River Irrigation Area LCDC Ord Land and Water Management Plan Conservation Group	Chairperson Member
Lachlan Dobson	Ord Land and Water Management Plan River Group	Member
Steve Grandison	East Kimberley Recreational Fishing Advisory Committee	Member
Simon Thorpe	Kununurra Tourist Bureau	Manager
Andrew McEwan and Hunter McEwan	Macka's Barra Camp	Owner
Tarnya Vernes	Ord Land and Water Management Plan Conservation Group Care of the Ord Valley Environment	Chairperson Member
Keeley Palmer	Ord Land and Water Management Plan River Group Care of the Ord Valley Environment	Member Member
Geoff Warriner	East Kimberley LCDC	Chairperson
Bevan Stott	Kimberley Land Council	Senior Policy Officer
Gordon Graham	Department of Environment and Conservation	Regional Ecologist
Paul Novelly	Agriculture Western Australia	Regional Director
Joe Sherrard	Agriculture Western Australia	District Manager
Leith Bowyer	Water and Rivers Commission	District Manager
Dave Harvey	Fisheries Western Australia	Project Officer
Warren Ford	Wesfarmers	Community Liaison Officer
Simon Rodgers	Water and Rivers Commission	Hydrologist
Paula Deegan	Water and Rivers Commission	Project Manager
Susan Worley	Water and Rivers Commission	Regional Manager
Bevan Bessen	Bessen Consulting Services	Facilitator

A4.3. Outcomes of Community Consultations

A 4.3.1. The June 2000 Workshop

This section presents the outcomes of the 17 June 2000 workshop at which community views on the social values of the Ord River were developed. Given the time since the workshop, the original Report to Participants is included below (as shaded text), with only some minor editing to make the format compatible with this document.

Report to Participants

Context

To provide community input into the Commission's Ord River Interim Water Management Plan, a half-day workshop was held in Kununurra on Saturday, 17 June 2000. Twenty-one community members attended as representatives of different groups and interests. Technical advice was provided by four Water and Rivers Commission staff and the workshop was facilitated by an independent consultant.

A number of evening meetings were held prior to the workshop to provide a briefing for interested participants and telephone discussions were held with all potential participants.

Focus

Participants were asked to consider the ecological water requirements of the Ord River and provide advice to the Commission on social and cultural values to help to determine interim EWP.

Outcomes

By the conclusion of the workshop, participants had:

- generated a range of issues to be considered in determining interim EWP;
- identified the impacts of possible future flows at designated points in river reaches;
- recommended key social values to be maintained in the Interim Plan period;
- identified further work and information that is needed as input to the decision-making process; and
- agreed on the next steps in the process.

Outcome One- Range of Issues

Context

- The scope of the workshop was outlined:
  - community consultation provides input to EWP decisions to be made by the Commission and recommended to relevant Ministers;
  - the Commission water allocation planning is taking place in the context of the Ord Stage 2 Supply Area proposal; and
  - the community reference group focus is on water flows in the lower Ord River (though many other water related issues have been raised through various prior consultative processes).
- Overall water allocation planning was described as an iterative relationship between:
  - Environmental Water Provisions (EWP);
  - Ecological Water Requirements (EWR); and
  - Consumptive Water Yield.

EWR and EWP were defined and the Scientific Panel advice on interim EWR was summarised and used as input to the workshop.

The Scientific Panel was not able to provide quantifiable EWR, due to the lack of data.

Rather, the Scientific Panel provided advice on likely impacts and on the level of ecological risk. They considered two potential future scenarios, both based on Stage 2 Supply Area flows but differing in their degree of seasonal variability:

- the potential future, low seasonality included a base flow in the dry season of 30 m^3/sec; and
- the potential future, high seasonality meant slightly higher wet season flows and very low or no flow in the dry season.

The recommendations of the Scientific Panel were presented (see Section 4.3)

Range of Issues

To provide examples and guide discussion, waterway values collated from previous consultations were considered by participants and added to during the workshop. These are listed in the table below.

Values	Management Objectives
Environmental**:**	
• remoteness, wilderness, isolation	• maintain wilderness character
• unpolluted	• protect water quality, no visual pollution
• diversity / habitat	• maintain ecosystem integrity
• vegetation, animals, ecological processes	
Social**:**	
• boating	• maintain community access
• recreation	• maintain a valued community asset
• indigenous	• manage for Native Title rights and traditional ownership
• multiple use/minimum conflicting impacts	• plan for compatible uses
Aesthetics:	Water quality, maintain unique character
• safety	• demonstrate duty of care
• fishing	• provide for shore based and boat based fishing
• sightseeing	• maintain character and integrity of the river
• historical	• manage for cultural value
Economic**:**	
• irrigation / power	• primary use of reservoir
• commercial fishing	• maintain opportunity and protect fish habitat
• tourism	• develop tourism with regard to environmental and social values
• aquaculture	• open to other economic development

Outcome Two- Impacts at Designated River Reaches

Participants familiarised themselves with the cross-section hydrological information available for five sites along the Lower Ord River (data for 22 sites was held by the WRC):

- Ivanhoe Crossing;
- Kimberley Research Station;
- Tarrara Bar;
- Skull Rock Boat Ramp; and

- Carlton Crossing.

The maps provided indications of relative levels for three scenarios:

- 1972-95 (dams, pre hydro);
- 1995-current (dams, post hydro); and
- Possible future (full allocation for Stage 2 Supply Area).

Participants then formed working groups to focus on each of the five sites in terms of:

- the social values and activities likely to be affected by post Stage 2 Supply Area flows;
- the likely impacts;
- recommendations, where possible, on:
  - depth;
  - flow;
  - duration;
  - frequency;
  - seasonality; and/or
  - annual variability.

It must be noted several participants were concerned that the cross-sections provided were not cross-sections of the designated site, but were taken at a slight distance upstream in two instances (Carlton Crossing and Skull Rock Boat Ramp). The outcomes from each working group are presented below:

Ivanhoe Crossing

Value	Important criteria	Recommendations
Recreation Fishing	• water to fish in all year • water quality • environment • lower flows possible as water may provide safe havens for fish (i.e: isolated areas that have no access) • maintain fish habitat	• wet season flow required • depth unknown • length of flow unknown
Tourism	• sightseeing requires that vegetation is maintained and some flow is maintained • drive across the historic crossing • needs water level not above bollards • levels of tourism usage in future are unknown • bird watching environment protected	• some flow maintained • current or lower dry season flow from May to December
Vegetation	• maintain diversity • tourism benefits • environmental health	

Kimberley Research Station

Value	Important criteria	Recommendation
Environment and Habitat	• a significant shallow bench will remain • Magpie Geese will continue to roost • Cumbungi and other basic vegetation communities will persist	• there will be no impact from possible lower flows

Tarrara Bar

Value	Important criteria	Recommendation
Healthy Environment	• bio-diversity • maintain ecological processes • fish stocks	
Healthy Riparian Area	• weed free • access to River and camping areas	
Water Quality	• needs to be a flow all year round and all down the River (no isolated pools in the dry season) • big flows in the wet season are probably a good thing, as long as they are managed properly	
Economics: Irrigation	• a decrease in River level will increase the cost of pumping from the River • need to be able to maintain water availability (unlike Goulburn River Irrigation Area 10 % allocation) • water value needs to be calculated because an environmental flow incurs a cost	allocation priorities: • environment and tourism • power • Ord Stage 1 • Ord Stage 2
Cultural: River Access	• Aboriginal people have fishing access to the bank at significant places Issues: • vegetation density (constant water) • freedom of access (along banks) • getting to the bank • places of Miriuwung, Gajerrong significance	• dry out time of one month (?) • plus wash out flush impact of 0.7 metre lower (from since 1995), significance not known
Tourism and Recreational	• need constant water in shallow areas	
Aesthetics	• need to maintain or enhance the look of the River. This means: • clean and clear water • fish • water flow (preferably not 4,000 m^3/sec that was released this year)	• Diversion Dam management • Communication • Flood Management Plan
Recreational Fishing	• protect Tarrara Bar as one of the few land based fishing platforms available • significant tourist area but shallow • reduction in flow will reduce value	• maintain some flow
Habitat	• unique Basalt outcrop and habitat relies on shallow running water on upper part • reduction of flow will affect this habitat • has deepest part of River at the lower end • reduction in flow will affect water quality in the pool • good fishing • unique habitat	• must be some flow maintained • some channels must flow all year

Skull Rock Boat Ramp

Value	Important criteria	Recommendation
Tourism (commercial and recreational)	• shift tourism to cover the whole year (increase the market) to take advantage of wet season flows • identify the time period when waterway users will be affected by lower flows	
Social, Environmental, Cultural and Economic River Use	• there should be an understanding that levels can not be continuously maintained	
Waterway Activity	• waterway activity may have to recognise that River reaches may be seasonally limited • on average, flows will enable river passage • water provided may be for the average flow not for permanent or continuous passage	

Carlton Crossing

Value	Important criteria	Recommendation
Water Quality	• the need for dilution of pollutants • maintain or enhance water quality	• ensure flows are sufficient to maintain water quality at desirable level • research need to be undertaken
Environment	• current habitat maintained • aquatic (fish) and non-aquatic (birds and plants)	• maintain current flows
Pastoral Activities	• saltwater/freshwater interface affects the watering of cattle downstream • border between two stations requires no shallow spots, to prevent cattle crossing • bogging of cattle in non-tidal areas if flows are reduced • need for drinkable water between 'The Rocks' and 'Green Island'	• small reduction in flow is possible but not a major reduction in flow
Recreational Fishing and Boating	• dry season access ensured: • safety in navigation • increased risk of people and crocodile interaction	• maintain current scenario • 'pulses' should continue to mimic natural scenarios
Tourism: Boating	• require a minimum depth of 0.6 metres between Tarrara Bar and Panton Island at the shallowest parts • needed all dry season (tide excluded) and every year • wildlife viewing • birds • crocodiles	• current flow scenario maintained • in regard to this recommendation, a written input was provided by one participant
Economic: Aquaculture	• with the saltwater/freshwater confluence, need to maintain sufficient dilution of saltwater with fresh water, around Panton Island	• research the implications of the movement of the interface • until results are known, maintain current flow levels

Outcome Three: Recommended Social Values to be Maintained

The information on the social values and activities likely to be affected by possible Stage 2 Supply Area flows was assembled into a matrix that grouped similar values across all sites.

The key social values to be identified were:

- water quality;
- economics;
- social and aesthetic;
- environment and habitat; and
- traditional ownership.

Within each social value cluster, a number of aspects were identified. These aspects are described below:

Social Value to be Maintained- Water Quality

Aspects	Important criteria	Recommendation
Recreation: Fishing	• water to fish in all year • water quality • environmental health	
Healthy Riparian Area	• weed free • access to river and camping areas	
Healthy Water Quality	• biodiversity • ecological processes • fish stocks	
Environmental: Water Quality	• the need for dilution of pollutants • maintain or enhance water quality	• ensure flows are sufficient to maintain water quality at desirable level • research needs to be done • needs to be a flow all year round and all down the river (no pools in the dry season) • big flows in the wet season are probably a good thing as long as they are managed properly

Overall Water Quality Recommendation

In terms of maintaining water quality, the recommendations are that there needs to be some flow maintained throughout the year. The level of flow may be less than the current flow as long as water quality can be maintained.

Social Value to be Maintained- Economics

Aspects	Important criteria	Recommendation
Irrigation	• a decrease in River level will increase the cost of pumping from the River • need to be able to maintain water availability (unlike Goulburn River Irrigation Area 10 % allocation) • water value needs to be calculated because an environmental flow incurs a cost	Allocation priorities: • environment and tourism • power • Ord Stage 1 • Ord Stage 2
Tourism (commercial and recreational)	• shift tourism to cover the whole year (increase the market) to take advantage of wet season flows • identify the time period when waterway users will be affected by lower flows	
Social, Environmental, Cultural and Economic River Use	• there should be an understanding that levels cannot be continuously maintained	
Tourism	• sightseeing requires that vegetation is maintained and some flow is maintained • drive across the historic crossing • needs water level not above bollards (at Ivanhoe) • levels of future tourism usage are unknown	• some flow maintained • standard dry season flow from May to September, or lower flow if appropriate
Tourism: Recreational Fishing	• protect Tarrara Bar as one of the few land based fishing platforms available • significant tourist area but shallow • a reduction in flow will reduce value	• maintain some flow
Tourism: Boating	• require a minimum depth of 0.6 metres between Tarrara Bar and Panton Island at the shallowest parts • needed all dry season (tide excluded) and every year • wildlife viewing • birds • crocodiles	• current flow scenario maintained.
Pastoral Activities	• saltwater/freshwater interface affects the watering of cattle downstream • border between two stations requires no shallow spots to prevent cattle crossing • bogging of cattle in non-tidal areas if flows are reduced • need for drinkable water between The Rocks and Green Island	• small reduction in flow is possible but not a major reduction in flow
Aquaculture	• with the saltwater/freshwater confluence, need to maintain sufficient dilution of saltwater with fresh water, around Panton Island	• research implications of movement of interface • until results are known, maintain current flow levels
Waterway Activity	• waterway users/activities may have to recognise that River reaches may be seasonally limited • on average, flows will enable river passage • water provided may be for the average flow not for permanent or continuous passage.	

Overall Economic Recommendations

In regard to irrigation, water availability must be maintained but the requirements of the environment, tourism and power are acknowledged. For most forms of tourism and for other economic uses such as pastoralism and aquaculture, a reduction in flow is acceptable, as long as some flow is maintained.

The main difference in recommendations is in the area of boat-based tourism. One recommendation is to maintain the current flow levels and ensure a minimum depth of 0.6 m below Tarrara Bar, at all times.

There are a number of other recommendations that some river reaches may be seasonally limited and that water should be provided for average flows, not for permanent or continuous passage. This will require changes in the management and operation of boat-based tourism enterprises, in terms of timing and location of operations.

Social Value to be Maintained- Social and Aesthetic

Aspects	Important criteria	Recommendation
Vegetation	• maintain diversity • tourism benefits • environmental health	
Tourism and Recreational	• need constant water at Bar or shallow areas	
Aesthetics	• need to maintain or enhance the look of the River This means: • clean and clear water • fish • water flow (preferably not 4,000 m^3/sec that was released this year)	• Diversion Dam management • communication • Flood Management Plan
Recreational Fishing and Boating	• dry season access ensured: • safety in navigation • increased risk of people and crocodile interaction • lower flows possible as water may provide safe havens for fish (i.e: isolated areas	• maintain current scenario • pulses should continue to mimic natural scenarios • wet season flow required • length of flow unknown • depth unknown

Overall Social and Aesthetic Recommendation

In terms of social and aesthetic values, the recommendation is to maintain some water flow at the shallowest bars throughout the year. The level of flow may vary from the current flows to the lower flow predicted under Stage 2 Supply Area.

Social Value to be maintained- Environment and Habitat

Aspects	Important criteria	Recommendation
Tourism	• maintain fish habitat • bird watching environment	
Environment and Habitat	• a significant shallow bench will remain at Kimberley Research Station • Magpie Geese will continue to roost • Cumbungi and other basic vegetation communities will persist	• there will be no impact from possible lower flows
Habitat	• at Tarrara Bar, a unique Basalt outcrop and habitat relies on shallow running water on the upper part • reduction of flow will reduce the number of channels flowing • reduction of flow will affect this habitat • has deepest part of River at lower end of Tarrara Bar • reduction in flow will affect water quality in the pool • good fishing • unique habitat	• must be some flow maintained • some channels must flow all year
Environment	• current habitat maintained • aquatic (fish) and non-aquatic (birds and plants)	• maintain current flows.

Overall Environment and Habitat Recommendation

The overall recommendation ranged from maintaining current flows to a recommendation that full Stage 2 Supply Area allocations proceed because no environmental impacts were expected. The need for some further work, such as that recommended by the Scientific Panel, was acknowledged.

Social Value to be Maintained- Traditional Ownership

Aspects	Important criteria	Recommendation
Cultural: River Access	• Aboriginal people have fishing access to the bank at significant places Issues: • vegetation density (constant water) • freedom of access (along banks) • getting to the bank	• dry out time of one month • plus wash out flush • impact of 0.7 m lower (from 'since 1995), significance not known
Cultural Sites	• places of cultural significance to the Miriuwung, Gajerrong and Dulbong peoples need to be recognised	

Overall Recommendation

Lower flows are acceptable but further consultation needs to be undertaken with traditional owners.

Outcome Four: Further work required

Participants worked in focus groups to identify the gaps in knowledge and to make recommendations for work that would help to clarify issues.

The suggestions were:

- more information needed on flow and level relationships:
  - need to establish if the current flow is the best environmental option (perhaps less flow overall, at different rates, maybe a better option);
  - need to establish what the water levels effectively will be, with a reduction in volume, along the length of the river;
  - do not know the relationships between volume flows, water levels, impacts on storage and water use requirements; and
  - hydrographical survey needed from the mouth to Kununurra Diversion Dam (including cross-sections and seasons).
- more information needed on impacts of lower flows:
  - need to know the effect that river level decreases have on the riverine environment
  - actual Stage 2 Supply Area water levels, including flows back into the river;
  - pump stations versus flow, how much water is taken out in the Carlton Crossing area;
  - identify critical spots on the river and study them;
  - need to know the impact of a reduction in average water level on vegetation, fish and other water life;
  - need to know if Ivanhoe or other rock barriers will become obstacles that inhibit dry season fish and aquatic movements; and
  - need to know what will happen to the Cumbungi and riparian areas; what is the impact of velocity and depth?
- more information on sedimentation processes:
  - need to consider the sedimentation mechanism from Panton Island upstream, before determining the bed and clearance levels in tidal sections and other River sections; and
  - need to know what happens to sediment loads if water flow decreases but water level stays the same.
- a comprehensive cost / benefit analysis for the social, economic and environmental uses of the River involving:
  - appropriate criteria agreed for the modelling;
  - doing the study;
  - providing information on the trade-offs that are involved;
  - assessing the risk factor associated with full irrigation and current environmental flow; and
  - developing water allocation priorities under conditions of shortage, i.e.: Stage 1 areas, Stage 2 developments, environment, tourism and recreation, by placing a monetary value on water.
- focus groups expressed this idea in a number of forms, i.e.:
  - do not know the economic use trade-offs, i.e.: between irrigation, pastoral, tourism, aquaculture
  - do not know the social use trade-offs between economic use, recreation values and aesthetic values;

  - do not know the potential impacts on present industries that are operating, e.g.: tourism or farming;
  - need to establish the value of recreation and environmental water use to compare with industry water use;
  - need to assess environmental, social and economic impact of minimal irrigation; and
  - need to establish criteria for balancing trade-offs between economic and socio-ecological values.
- more information on impacts in tidal areas:
  - revisit the data to define tidal effects and salinity mixing regimes under a range of flow scenarios. This will give answers for aquaculture and can be used as input to the modelling in the Ord Bonaparte Project.
- investigation of social impacts of proposed changes:
  - how practical is the mapping of rock bars and River reaches;
  - investigate the use of jet boats for access to shallower River reaches;
  - survey the local level of recreational fishing, in terms of activity and catch;
  - survey the acceptability of change (for various components);
  - social research and broader community consultation needed; and
  - determine community acceptance of Stage 2 Supply Area; what is the economic value of Stage 2 Supply Area compared with our current and future values?.
- need to consider traditional owners' perspective:
  - need to know from traditional owners about the responsibilities and impacts of river use and change;
  - need to understand traditional ownership issues; and
  - be clearer on cultural values.
- management questions:
  - need to know the impact that possible fluctuating Kununurra Diversion Dam levels will have on Lake Kununurra;
  - need to work out how to properly manage flows (manipulate for environmental management);
  - need to know the impact of natural weirs on levels and the options to narrow certain channels to deepen water levels in backed up areas;
  - further identification of information shortage priorities, i.e.: flow effect on River level from Diversion Dam to the mouth of the River; and
  - what is the amount of water that is available, i.e.: irrigation values.

Workshop Recommendations (on further work)

The first priority is to provide data on the relationship between volume flows and water levels in the River. Participants are particularly keen to see a map/schematic of actual water levels along the River under a range of potential flow regimes.

A second priority is to focus on the sedimentation mechanisms and the effects of different flow regimes on sediment build-up.

A third priority is to design, conduct and promote the outcomes from a comprehensive cost / benefit analysis in order to provide base data for the decisions on competing users.

These recommendations can be compared with the recommendations for further work from the Scientific Panel.

Their recommendations are:

- the priority investigations that would be needed to establish the water level/habitat relationship are:
  - survey of additional channel cross-sections so that a better estimate can be made of the impacts of changes in base flow levels on shallow and deeper habitats;
  - field verification of the accuracy of the modelled outputs of discharge versus stage heights;
  - more data, if available, on actual releases from the Kimberley Diversion Dam for the period 1972-95 and analysis of the variability of releases. Anecdotal information may be needed to supplement dam gates operational records; and
  - survey of species supported by different habitat types within the Ord River, so that changes in critical habitat can be modelled for different base flow scenarios.

In addition to the further work described above, the Scientific Panel recommended a number of other studies and monitoring. The monitoring recommendations include:

- comprehensive flow monitoring downstream of Kimberley Diversion Dam;
- long term monitoring of channel cross-sections linked to vegetation transects to determine the relationship between sedimentation and vegetation encroachment and the effects on channel capacity and habitat area;
- standardised monitoring of invertebrates and fish community structure;
- water quality monitoring. The Panel recognise that a program is in place but recommend it be reviewed to ensure event-based and/or continuous monitoring, sediment sampling and pesticide monitoring in targeted fish species;
- current crocodile monitoring should continue;
- investigation of the effects of the 1999-2000 wet season flood flows on sediment movement and vegetation response. The impacts, if any, on sediments and channel form will indicate the potential for manipulation of the Kimberley Diversion Dam operation to manage depositional processes; and
- investigation of the importance of floodplain flooding to vegetation, invertebrates, fish and waterbirds.

Outcome Five- Next Steps

The workshop agreed on the following steps:

- collation of the workshop outcomes, in terms of:
  - values and activities identified;
  - critical values flagged; and
  - comparison to the outcomes of the Scientific Panel on EWR
- distribution of the report from this workshop to all participants:
  - to provide a record of the work done; and

  - as an indication of the further work considered important by the group.

- forums for further input at the local level, via such mechanisms as the Ord Land and Water Management Plan process;
- Interim Plan for Water Strategy completed by the Commission and containing:
  - report from the Scientific Panel on EWR;
  - workshop record from the Community Reference Group; and
  - comment on how the issues and questions raised are being addressed.
- input to Interim Plan from other Agencies;
- constant iterations of:
  - Environmental Water Provision;
  - Ecological Water Requirements; and
  - Consumptive Water Yield.
- new water licences under the Revised Interim Water Management Plan will be required to undergo a formal EPA assessment process.

A 4.3.2. The October 2000 Workshop

On 25 October 2000 participants from the June Community Reference Panel, and others, attended a briefing and discussion of the Commission's progress with revising the Interim Water Management Plan. The workshop provided an update to community members on how the Commission had incorporated the advice of the Scientific Panel and outcomes from the previous Reference Panel workshop into a revised water allocation strategy for the Ord River. The intention was for feedback from the meeting to be used in finalising the revised Interim Water Management Plan.

Commission representatives outlined the main elements of the allocation strategy, and then covered in more detail the proposed interim EWR and the implications of fully meeting these for consumptive use allocations. The rationale behind using channel wetted perimeter as a measure of change in habitat area was described, the effect of different options identified and the Commission's current preference for 45-40 m^3/sec minimum flow regime as the interim EWR elaborated.

The strategy made provision for 310 GL/yr to be diverted to the Stage 1 areas (at 95 per cent reliability) and a range of options with different diversion quantities and reliabilities for the M2 Supply Area. The options ranged from 625 GL/yr at 95 per cent reliability to 710 GL/yr at 87 per cent reliability. The presentations concluded with an invitation to make written submissions to the Commission on the strategy so these could be considered when finalising the revised plan.

Discussion from the floor made the following major points:

- while many acknowledged that the proposed EWR protected most of the in-stream values identified by the Scientific Panel and the June Workshop, a number of delegates were concerned that the impact on the reliability of supply to the M2 Supply Area was excessive;

- commercial tourism interests on the lower Ord River remained concerned that navigation would still be difficult under the revised proposals;
- the need for the introduction of improved on-farm practices was raised by one delegate, although the cost of carrying out such improvements was highlighted by others;
- there was concern that inadequate water allocation had been made to cover planned short term growth within the Stage 1 areas, and particularly in self supply usage; and
- the allocation strategy did not recognise the role of Indigenous people in ecologically sustainable use of the environment, and could compound the environmental problems caused to the lower Ord River by the Ord Stage 1 development. It had not carried out cost/ benefit studies that included consideration of the social-economic impacts on local Aboriginal people.

Other points of concern raised or re-emphasised included:

- risks and uncertainty about measuring the achievement of target improvements i.e. the monitoring may not reflect the effect of the whole Stage 1 channel and drainage systems;
- reliability of hydrological data used in estimating the total allocation volumes proposed- the 51 cross-sections not enough for environmental information;
- the Water Corporation's and Commission's capacity to manipulate flow to meet EWP given variables;
- EWR decisions being made on more recent flow history post raising of spillway rather than on longer flow history from dam construction until then;
- lack of assessment of regional scale economic benefits of further development and how traditional owners may share in the benefits – only environmental and consumptive water allocation trade-offs were considered);
- the difficulty in quantifying the intangible social and community benefits of the river;
- the need to take a minimal approach to EWR so that irrigation needs could be met;
- the very high costs to individual farmers to meet efficiency targets; and
- tour operators might be willing to pay something for their use of the water, but would expect similar rights as the farmers.

Two written submissions, one from a river pumper and the other from the Kimberley Land Council (KLC), were received by the end of November and supported the positions described in the last two dot points. In particular, the KLC submission stated that the Interim Water Management Plan should be delayed until the proposed cultural values study had been completed.

Further written submissions were received from Stage 1 irrigators and M2 Supply Area proponents between late December and March in response to additional specific briefings. Submissions from Stage 1 irrigators centred on obtaining more water to cover an expected move to sugarcane while the M2 Supply Area submission sought higher reliability of supply (see Section 5.2.3).

The Commission endeavoured to address the major concerns raised at the workshop and in the subsequent submissions when finalising the revised Interim Water Management Plan (this document). Examples where significant changes or commitments were made include:

- additional allocation to Stage 1 areas (channel supplied areas and for self supply) to account for short term growth and the expected move to more sugarcane production;
- development of a drought period EWP to reduce the severity of restrictions on consumptive uses without excessively increasing the risks to aquatic ecosystems developed since regulation; and
- commitments to manage the flow regime, within the practical limits of the existing structures, to influence riparian vegetation so that access to important Aboriginal ceremonial and other sites can be maintained.

The remaining points raised were best addressed through the licensing process or through ongoing communication and development of the next allocation plan.

A 4.3.3. Aboriginal Cultural Values Study

The Commission engaged Barber and Partners in May 2001 to carry out a specific study of Aboriginal cultural values associated with Ord River. The study was to build on the initial information obtained from the June 2000 workshop at which the need to carry out detailed consultation with traditional owners was recognised. Barber and Partners were selected in consultation with the Kimberley Land Council (KLC). At the time a number of representative bodies might have taken this role. The KLC was considered the appropriate representative body as Senator Heron had recently identified the KLC as the regionally representative body for Native Title consultation. This approach was supported by advice from Environment Australia. In addition, the Commission had already conducted a similar cultural values project through liaison with KLC in the West Kimberley and it presented an opportunity to build on an established process.

The focus area of this study is shown in Figure 7 and includes the Ramsar listed lower Ord wetlands, groundwater, springs, floodplain, smaller watercourses, riparian zones and adjacent integral land. Within this area, the consultant was expected to:

- develop protocols for the provision of information, and measures to protect the intellectual property rights of Aboriginal people providing the information and cultural sensitivities;
- articulate Aboriginal values of, and interests in, water as a cultural and natural resource;

- identify and document environmental features and ecological processes dependent on surface water (e.g. seasonal flows, river pools, natural barriers, vegetation, aquatic biota) regarded as culturally, socially and economically important to Aboriginal groups with traditional links to the Ord watercourses;
- identify and map any riparian areas and adjacent land integral to the identified water features;
- describe the nature of and linkages between any of the identified water and related land features, and describe the Aboriginal values they possess (e.g. resource use patterns, seasonal calendars, story places, etc.);
- provide an assessment of the significance of these ecological features with respect to the Aboriginal values they possess;
- identify and document impacts of current dam structures, water use, and flow regimes on Aboriginal values and ecological features of importance to Aboriginal people;
- investigate any distinction between Aboriginal values relating to environmental features of pre- and post-regulation river systems;
- make recommendations regarding the minimisation or avoidance of negative impacts, or the enhancement of positive impacts, on water-dependent Aboriginal values; and
- integrate the findings in a report that ensures the outcomes are understood and endorsed by the Aboriginal people involved.

The study is being conducted in a way that ensures:

- the appropriate people are consulted and the geographic scope of their interest is established;
- traditional owners with knowledge of the Ord River study area have every opportunity to actively contribute;
- the links between the study, waterway management, the Water Management Plan for the Ord River are clear;
- the intellectual property rights of Aboriginal participants are protected;
- recommendations of the study are endorsed by Aboriginal participants;
- Aboriginal participants are recompensed for the provision of their knowledge to the study.

Both KLC and the Department had anticipated that the cultural values study could be conducted in conjunction with an Aboriginal Socio-Economic Impact Assessment (ASEIA) proposed by the DRD as part of the Aboriginal consultation for a Framework State Agreement with traditional owners over the whole Ord Stage 2 Supply Area. Because of delays with the ASEIA process, this project went ahead independently. However, the delays have meant that the results of this study would not be available to inform this Interim Water Management Plan. It was expected that the study would be completed by November 2001 and the completed work would be subjected to peer review. The consultants are closely liaising with Aboriginal groups with traditional lands in the study area and conducted fieldwork under the guidance of senior people from these groups.

Appendix 5. Irrigation demands

This appendix summarises information used to calculate the upper limits of average water year demand adopted for the Stage 1 and M2 Supply Areas. These demands were used to develop the allocation strategy of this revised plan.

A5.1. Stage 1 areas

A 5.1.1. Areas supplied by the Ord Irrigation Co-operative

Table A5.1 lists the information used to establish irrigation water needs for the areas supplied from the M1 Supply Area and Packsaddle Channel Distribution Systems. Footnotes to the table summarise the distribution and on-farm losses assumed. The table reflects the water requirements for average rainfall conditions over the area supplied by the OIC (estimated as 775 mm/yr the median water year total for November to October between 1905-06 and 1991-92). When these water requirements are fully met, crop growth should not be limited by available soil moisture.

The Ord Irrigation Co-operative (OIC) argued that over 95 per cent of the current freehold land within the channel distribution systems would be irrigated as cost-price pressures forced irrigators to intensify their operations. Aerial photography suggested that 86 per cent[74] was developed for irrigation in 2000. While not all this area is planted every year (for a range of reasons including ownership change, private financial constraints etc.[75]) some areas are cropped twice in one year. For example, if short growing season (horticultural) crops are planted early (towards the end of the wet season) a second crop is often established by the middle of the dry and reaches maturity well before the next wet season. In addition, cover crops are being promoted to minimise erosion risks on otherwise bare soil during the wet season. These may require an initial watering to get them established.

The Department considered that these trends in farm management should be recognised in the allocation, but not to the degree proposed by the OIC. An irrigable area based on 92.5 per cent[76] of the current developed farms plus the additional areas for which clearing applications had been lodged with the Soil Conservation Commissioner was adopted. The final mix of crops, areas and provision for double cropping adopted for the areas supplied by the OIC are shown in Table A 5.1.

The crop water requirements of the main crop types grown in Stage 1 areas were based on estimates from Agriculture WA (Dr J Sherrard) supported by preliminary results from local field work. A monthly irrigation water demand model was developed

[74] Based on 2000 aerial photography as interpreted by Whelans Ltd, surveyors contracted by Water Corporation for OIC.

[75] Areas actually planted, as reported to Agriculture WA in the 1999 season, were only 75 per cent of the total farm boundaries.

[76] Estimated per cent area utilised after provision is made for on-farm infrastructure.

as part of the economic modelling studies (White, 2001), and adapted to calculate the monthly irrigation requirements for each crop. The irrigation requirement varies with the amount of rain that falls over the irrigation area each month. Table A5.1 summarises the average irrigation requirements for each crop under average rainfall conditions for the area supplied by OIC. The average rainfall conditions were based on monthly rainfalls for the period April 1906 to March 1992.

Table A5.1 Irrigated areas and average crop water demands for areas supplied by the OIC

Crop Type	**Area irrigated at least once during season**	**Total area* irrigated within irrigation season**	**Crop** water req'ment**	**Irrigation water required by the crop*** **	**Irrigation water required at the farm gate***** **		**Irrigation water required at diversion point(s)****** **
	(ha)	**(ha)**	**ML/ha**	**ML/ha**	**ML/ha**	**GL**	**GL**
Bananas	65	65	24.1	20.2	25.2	1.6	2.1
Chickpeas	170	170	5.0	5.0	7.2	1.2	1.5
Cotton	500	500	7.7	7.6	10.9	5.4	6.8
Fresh beans	160	191	4.4	4.4	5.5	1.0	1.3
Honeydew	450	540	4.0	4.0	5.7	3.1	3.9
Hybrid seeds	352	379	5.3	5.3	7.6	2.9	3.6
Leucaena	700	700	16.5	11.0	15.7	11.0	13.7
Mangoes	363	363	11.6	8.1	10.1	3.7	4.6
Pumpkin	460	460	6.2	6.1	8.8	4.0	5.1
Red grapefruit	0	0	15.9	10.6	13.2	0.0	0.0
Rockmelon	700	840	4.0	4.0	5.7	4.8	6.0
Sandalwood	1,000	1,000	12.8	8.2	11.8	11.8	14.7
Sugarcane	8,940††	8,940	22.1	16.7	23.4†	209.0†	261.2
Sweet corn	110	122	5.2	5.2	7.4	0.9	1.1
Watermelon	600	671	6.2	6.1	8.8	5.9	7.4
Totals (Ha)	14,570	14,940				266	333

* Includes provision of those areas where two crops are planted within the one season on the same area
** Water required by the roots of the crop to ensure growth is not limited by moisture availability
*** The additional (irrigation) water needed to be supplied to the crop to supplement the available soil water from rainfall, so that the crop receives its full crop water requirement
**** Based on 70 per cent of the water delivered at the farm gate reaching the crop if supplied using furrow irrigation methods and 80 per cent if delivered via under-tree sprinkler or drip irrigation methods
*****Based on 80 per cent of the water diverted from Lake Kununurra being delivered to supply points on farms in the OIC Supply Area. (That is a 80 % distribution efficiency)
† 1200 ha of sugarcane is to be watered by furrow irrigation combined with on-farm recycling on Green Location. This is expected to achieve an 80 per cent on-farm efficiency. Averaged on-farm efficiency for the 8940 ha of sugarcane is therefore 71.3 per cent
†† A further 60 ha is expected to be established by irrigators that pump direct from the Ord River or Lake Kununurra

Additional provision of water for leaching salts past the root zone was not considered necessary. O'Boy *et al. (*2001) showed that significant groundwater recharge occurs during the wet season of wet years when irrigation is not taking place. While not occurring in normal years, the periodic wet year would leach any accumulated salts that may accumulate in the plant root zone between recharge and leaching events. It is unlikely that salt accumulation over the period between recharge years would affect crop yields. Accumulation has not been evident in Stage 1 areas to-date, although the development of high water tables as a result of past irrigation operations, now poses a different water logging and salinity threat.

Additional water must be diverted at the farm gate to ensure that the crop receives its irrigation water requirement at its roots. The Department adopted on-farm efficiencies of 70 per cent for furrow irrigation without recycling, 80 per cent with recycling and 80 per cent for under-tree sprinkler and drip systems. These have been negotiated with the OIC, and although slightly higher than proposed in the community's Land and Water Management Plan (Ord Land and Water, 2000) are considered by the Commission to be readily achievable. They were adopted after studying reviews of irrigation efficiencies (Clements *et al*., 2000) and set as targets for the end of the OIC licence period (see Section 5.2). Distribution losses between the point of diversion and the farm gate also need to be considered. After a similar review of Australian practice (ANCID, 2000), and consideration of the channel lengths and volumes flowing through the (Stage 1) M1 and Packsaddle Channel systems, a target distribution of 80 per cent was established.

A 5.1.2. Self supply areas

Table A5.2 (next page) lists the information used to estimate the water needs of irrigators that pump directly from Lake Kununurra and the Ord River within 15 km of the Kununurra Diversion Dam. The areas were based on developed land in the year 2000 plus an allowance for growth based on clearing applications that had been made at the time. Footnotes to the table summarise the distribution and on-farm losses assumed. The minor differences in irrigation water requirements of the crops between Table A3.1 and A3.2 reflect the difference in average rainfall and rainfall effectiveness over each area (775 mm/yr compared with 755 mm/yr).

In addition to self supply diversions for irrigation, water is also diverted for public and commercial purposes in and adjacent to Kununurra. Current self supplied diversions for public and commercial purposes total about 0.3 GL/yr, although this is expected to increase as the town grows. This self supply demand is unlikely to exceed 1 GL/yr.

Table A5. 2 Adopted areas and average water needs of crops supplied directly from the Ord River

Crop Type	Areas irrigated in 2000	Adopted* irrigated area *	Crop** water req'ment	Irrigation water required by the crop***	Irrigation water needed at the end of pipe ****		Irrigation water needed at diversion point †
	ha	ha	ML/ha	ML/ha	ML/ha	GL	GL
Bananas	70	154	24.1	20.3	25.4	3.9	4.1
Chickpeas	0	0	5.0	5.0	7.2	-	-
Cotton	0	0	7.7	7.6	10.9	-	-
Fresh beans	0	0	4.4	4.4	5.5	-	-
Honeydew	44	111	4.0	4.0	5.7	0.6	0.7
Hybrid seeds	50	56	5.3	5.3	7.6	0.4	0.4
Leucaena	0	0	16.5	11.0	15.8	-	-
Mangoes	241	363	11.6	8.1	10.2	3.7	3.9
Pumpkin	45	70	6.2	6.1	8.8	0.6	0.6
Red grapefruit	6	56	15.9	10.7	13.3	0.7	0.8
Rockmelon	36	98	4.0	4.0	5.7	0.6	0.6
Sandalwood	0	0	12.8	8.3	11.8	-	-
Sugarcane	0	60	22.1	16.8	24.0	1.4	1.5
Sweet corn	0	0	5.2	5.2	7.4	-	-
Watermelon	79	147	6.2	6.1	8.8	1.3	1.4
Totals	570	1116†				13.3	14

* Provides for an increase in irrigated area since 2000 and includes a provision for areas where two crops are planted on the same area during the one season. The additional area provision totals 546 ha

** Amount required by the roots of the crop to ensure that its growth is not limited by water

*** The additional (irrigation) water needed to be supplied to the crop to supplement the available soil water from rainfall, so that the crop receives its full crop water requirement.

**** Based on 70 per cent of the water supplied at the pipe outlets within the farm (termed end of pipe), reaching the crop if furrow irrigation methods are used, or 80 per cent if sprinkler or drip methods are used

***** Provides for 5 per cent losses between the point of diversion and the pipe outlets

† The self supply areas upstream and downstream of the Diversion Dam were 580 ha and 536 ha respectively

A5.2. Stage 2 developments

A 5.2.1. The total M2 Supply Area

Table A5.3 lists the information used to estimate the water required to irrigate sugarcane throughout the M2 Supply Area as intended by the previous proponents under their M2 Sugar Project. The M2 Supply Area has an estimated median rainfall from 1906-67 to 1991-92 of 787 mm compared with 755 mm for the M1 Supply Area. This is the reason for the minor differences in the sugarcane irrigation water requirement between the two areas.

Table A5.3 Maximum crop areas and water demand in the M2 Supply Area

Crop Type	Total Farm Area	Total area* irrigated	Crop** water req'ment	Irrigation water required by the crop***	Irrigation water required at the farm gate****		Irrigation water needed at diversion point *****
	ha	ha	ML/ha	ML/ha	ML/ha	GL	GL
Sugarcane	30,500	28,210	24.1	16.6	20.8	586	692
Other crops	0	0	0	0	0	0	0
Totals	30,500	28,210				586	692

* Provides for 7.5 % of the gross farm area to be internal roads, or irrigation and other farm infrastructure
** Amount required by the roots of the crop to ensure growth is not limited by water
*** The additional water that must be supplied by irrigation to supplement the available soil moisture generated from rainfall so that the crop receives its full crop water requirement
**** Based on 80 per cent of the water delivered to the farm being available to the crop, as all farms are to have on-farm recycling systems.
***** Based on 85 per cent of the water diverted from Lake Kununurra being delivered to supply points on farms in the M2 Supply Area (That is, a distribution efficiency of 85 % is assumed)

A distribution efficiency of 85 per cent was adopted for the M2 Supply Area following review of efficiencies currently being achieved by other Australian irrigation service providers. A higher figure of 90 per cent had previously been considered achievable, mainly because of modern design of the distribution system, and balancing storage and automatic control systems. While this may be achieved, it will be difficult, particularly in wet years. The Department considered that adopting 85 per cent for distribution efficiency was reasonable if no provision was made for leaching water. In dry years, when it is more likely to achieve better than 85 per cent distribution efficiency, the additional water would be available to provide a leaching fraction if this became necessary. A five per cent difference in distribution efficiency is similar to a 1 ML/ha leaching provision.

A 5.2.2. The M2 Supply Area in Western Australia

The gross farm area of the M2 Supply Area in Western Australian is approximately 16,000 ha. Using the same assumptions as used to estimate the average demand for the whole of the M2 Supply Area, the maximum expected demand in the Western Australian part of the M2 Supply Area is estimated as 362 GL/yr in a year with median rainfall (see Table A5.4). The maximum demand is not expected to exceed 400 GL/yr unless approval was given to develop an additional 10 per cent of land in Western Australia.

Table A5.4 Maximum crop area and water demand in the WA part of the M2 Supply Area

Crop Type	Total farm area	Total area* irrigated	Crop** water req'ment	Irrigation water required by the crop***	Irrigation water required at the farm gate****		Irrigation water needed at diversion point *****
	ha	ha	ML/ha	ML/ha	ML/ha	GL	GL
Sugarcane	16,000	14,800	24.1	16.6	20.8	307.8	362
Other crops	0	0	0	0	0	0	0
Total	16,000	14,800					362

* Provides for 7.5 % of the gross farm area to be used as internal roads, or irrigation and other farm infrastructure

** Amount required by the roots of the crop to ensure growth is not limited by the availability of water

*** The additional (irrigation) water needed to be supplied to the crop to supplement the available soil water from rainfall, so that the crop receives its full crop water requirement

**** Based on 80 per cent of the water delivered to the farm being available to the crop, as all farms are to have on-farm recycling systems

***** Based on 85 per cent of the water diverted from Lake Kununurra being delivered to supply points on farms in the M2 Supply Area (That is, a distribution efficiency of 85 % is assumed)

A 5.2.3. Additional areas downstream of Kununurra Diversion Dam

Two groups of potential irrigation developments occur downstream of the Kununurra Diversion Dam. The first group is based on additional (mainly self supply) developments occurring near the current Stage 1 areas and has been termed additional West Bank and miscellaneous areas. The second group is located downstream of Tarrara Bar on the Mantinea Flats and Carlton Plain soils where new distribution systems are proposed. All these additional developments would necessitate approvals from the Soil Conservation Commissioner and the EPA before they could proceed.

Table A5.5 summarises the estimated crop areas and water needs for both groups. The crop areas are based on a most likely scenario developed by the Ord Development Council and Agriculture WA during 2000. Some minor changes were made to reflect recent development applications[77] in the West Bank and miscellaneous area. The crop water demands are the same for both area types and other self supply areas (Table A5.2). The West Bank and miscellaneous area efficiencies were assumed to be the same. In the downriver development areas, the 1,800 ha of L*eucaena* will be grown on the black soils of Carlton Plain and assumed to be supplied by a channel and furrow distribution system with the same efficiencies as the areas supplied by OIC. Other areas were assumed to be supplied by a pressurised pipe distribution system of higher distribution efficiency and able to provide head for micro-sprinkler and drip systems. A 82 per cent on-farm efficiency (for the sprinkler systems supplied by the pressurised distribution system) was adopted. This is slightly higher than for the Stage 1 areas as further efficiency gains should be achievable by the time these areas are developed.

[77] Areas from Table A5.4 and the areas in the Table A5.2 footnote must be added to get areas of the west bank and miscellaneous scenario.

Table A5. 5 Adopted areas and average water needs for West Bank and downriver areas

Crop Type	Future growth in West Bank & misc areas	Irrigation water required at the end of pipe- West Bank & miscellaneous areas ***		New areas down stream of Tarrara Bar	Irrigation water required at the end of pipe- d/stream of Tarrara Bar***		Irrigation water required at diversion points*****		
							West Bank + Misc.	D/s of Tarrara Bar	Total
	ha	ML/ha	GL	ha	ML/ha	GL	GL	GL	GL
Bananas	0	25.4	0.0	500	24.7	12.4	0.0	13.4	13.4
Chickpeas	0	0	0.0	0	0	0.0	0.0	0.0	0.0
Cotton	0	0	0.0	0	0	0.0	0.0	0.0	0.0
Fresh beans	0	0	0.0	0	0	0.0	0.0	0.0	0.0
Honeydew	69	5.7	0.4	350	5.6	1.9	0.4	2.1	2.5
Hybrid seeds	160	7.6	1.2	0	7.4	0.0	1.3	0.0	1.3
Leucaena	0	0	0.0	1800	15.8	28.5	0.0	35.6†	35.6
Mangoes	292	10.2	3.0	1750	9.9	17.3	3.1	18.8	22.0
Pumpkin	98	8.8	0.9	200	8.5	1.7	0.9	1.9	2.8
Red grapefruit	316	13.3	4.2	4205‡‡	13.0	54.7	4.4	59.4	63.8
Rockmelon	100	5.7	0.6	300	5.6	1.7	0.6	1.8	2.4
Sandalwood	0	0	0.0	0	0	0.0	0.0	0.0	0.0
Sugarcane	0	0	0.0	0	0	0.0	0.0	0.0	0.0
Sweet corn	0	0	0.0	212	7.2	1.5	0.0	1.7	1.7
Watermelon	60	8.8	0.5	200	8.5	1.7	0.6	1.9	2.4
Totals	1095		10.7	9520		121	11.3	137	148

** Water required by the roots of the crop to ensure growth is not limited by moisture availability
*** The additional (irrigation) water needed to be supplied to the crop to supplement the available soil water from rainfall, so that the crop receives its full crop water requirement
**** Of the water supplied to pipe outlets within the farm (termed “end of pipe”), 82 per cent reaches the crop when supplied via sprinkler or drip methods. Only Leucaena is supplied via furrow with an assumed 70 per cent efficiency
***** Allows for 5 per cent losses between the point of diversion and the “end of pipe” outlets
† Leucaena is assumed to be supplied by a channel distribution system at a distribution efficiency of 80 per cent
‡‡ Note the 4200 ha of red grapefruit. Previous estimates (May 1999) assumed 5000 ha of bananas

Appendix 6. Water quality management of contaminants in drainage waters

A6.1. Background

Risks of downstream contamination will remain while irrigation return flows continue and highly toxic pesticides are in use. During the five years when irrigation return flows are being reduced and best management pesticide use is introduced, the quality of drainage waters should not exceed National Water Quality Guidelines levels for priority chemicals (ANZECC and ARMCANZ, 2000).

The approach adopted is based on the June 2000 National Water Quality Guidelines for fresh and marine waters. This involves establishing a management objective for the environment to be protected, adopting water quality guidelines that will support the management objective or designated use, and setting water quality objectives against which performance can be assessed.

A6.2. Management objective

The management objective is to protect the aquatic ecosystem health of the lower Ord River so that the environmental and recreational values, established since the construction of the Ord River Dam, and the cultural values that the traditional owners of the area have for the river, are maintained. These include protection of ecological values and water based recreational activities, particularly recreational fishing. In turn, this requires the maintenance of a well oxygenated, flowing river that provides habitat for current aquatic fauna species and maintains ecological processes in the river, and which minimises the risk of water quality contamination events impacting the aquatic biota.

The Department's revised interim EWP sets a minimum flow rate which will, in part, help maintain a healthy lower Ord River. However, the EWP needs to be complemented by a management regime that will minimise the risk of water quality contamination events occurring. Appropriate local guideline levels and water quality objectives are required to be set for pesticides in water draining the ORIA at levels that will not cause serious downstream river contamination given the proposed flow regime.

A6.3. Guideline levels

The National Water Quality Guidelines for concentrations of toxicants are developed for three broad types of aquatic ecosystems depending on their condition. These are high conservation/ecological value systems, slightly to moderately disturbed systems, and highly disturbed systems. For this assessment the lower Ord River is seen as a slightly to moderately disturbed system and the drains of the ORIA as highly disturbed systems. For toxicant concentrations in drainage waters, the trigger or guideline levels for a disturbed environment are set at levels that protect 90 per cent of species used in toxicity testing (Table 3.4.1 - ANZECC and ARMCANZ guidelines). For organochlorine pesticides a higher level of protection (based on protecting 95 per cent of species) is required, to account for the risks associated with biological accumulation. Where acute or chronic toxic effects occur to key species at lower concentrations than initially selected, then a higher protection level is appropriate. Using this approach guideline concentration levels for priority chemicals were selected. These are listed in Table A6.1.

Table A.6.1. Proposed guideline levels for contaminants in Stage 1 drainage waters and the lower Ord River

Contaminants – currently measured and with toxicology data available	**Proposed Guideline Concentration[1]**	
	in drainage waters (µg/L)	**for Ord River waters (µg/L)**
Aldrin	ID	ID
Atrazine	13	0.7
Bromophos ethyl		
Chlordane -total	0.08	0.03
Chlorfenvinphos		
Chlorpyrifos	0.01	0.01
pp' - DDE	ID	ID
pp' - DDT	0.01	0.006
Diazinon	0.01	0.01
Dicofol	ID	ID
Dieldrin	ID	ID
Endosulfan - total	0.2	0.03
Endrin	0.02	0.01
Fenitrothion	0.3	0.2
HCB		
Heptachlor	0.09	0.01
Lindane	0.4	0.2
Malathion	0.2	0.05
Methoxychlor	ID	ID
Parathion	0.01	0.004

1 From ANZECC and ARMCANZ Guidelines (2000) -Table 3.4.1;
ID – Insufficient data on toxicity tests to set a level

A6.4. Water quality management actions

Given the above guideline levels the following water quality objectives were adopted:

- progressive reduction in the number of samples exceeding the guideline level each year; and

- if guideline levels are exceeded follow-up actions are initiated to investigate the source, initiate corrective action and ensure future improved performance.

The licensee must develop protocols for the investigation and implementation of actions to improve performance in their water management improvement plan.

A6.5. Upgrading water sampling protocols and revising target levels

To date the water sampling for the presence of toxicants has been based on monthly sampling of drainage water biased to the lower ends of the drainage system. While this has proved very useful, particularly when comparing samples from input water quality and rivers and creeks unaffected by irrigation, improved random sampling strategies are required to identify sources and establish statistically valid testing of whether target levels are being exceeded or not. The new approach is currently being introduced.

The methodology outlined in previous sections of this appendix will continue until sufficient data is available to establish statistical variability under the new sampling regime (two to three years). At that time the monthly sampling program will be reviewed and rationalised. Continuity of performance measurement will need to be a consideration.

The new sampling approach is to be based on randomly selected block scale paired sampling where the local quality of input water to the block is compared with drainage output from the block. Statistics of the differences are studied and the random selection process enables all areas of the District to be covered over the dry season at reasonable cost.

Details of the approach are to be discussed with the Management Board of Ord Land and Water and the directors of Ord Irrigation Co-operative with the intention of inclusion in the sampling protocols of the OIC operating strategy.

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Abbreviations

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval (of a specified peak flow rate or flood flow)
DEH	Department of Environment and Heritage (Commonwealth)
DoIR	Department of Industry and Resources (formally DRD)
DRD	Department of Resources and Development
EPA	Environmental Protection Authority
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
ERMP	Environmental Review and Management Program
FRP	Filterable Reactive Phosphorus
NT	Northern Territory
OIC	Ord Irrigation Co-operative
OLWMP	Ord Land and Water Management Plan
ORDHP	Ord River Dam Hydro-electric Power Station
ORIA	Ord River Irrigation Area
RIWI Act	*Rights in Water and Irrigation Act 1914*
The Commission	Water and Rivers Commission
The Department	Department of Water
The District	Ord River Irrigation District
The Scientific Panel	A panel of river ecologists, established to advise the Water and Rivers Commission on revision of the 1999 lower Ord Interim EWP
TP	Total Phosphorus
WA	Western Australia

Glossary

Abstraction	The permanent or temporary withdrawal of water from any source of supply, so that it is no longer part of the resources of the locality.
Aboriginal heritage	Includes both the physical and cultural aspects and relates to the significance of places and objects to Aboriginal people in terms of traditions, observations, customs and beliefs.
Allocation limit (AL)	The quantity of water available for consumptive use, after Environmental Water Provisions and domestic requirements have been set. Domestic Allocation: refers to the volume of water required for household purposes and the irrigation of a small domestic garden.
Aquifer	A geological formation or group of formations capable of receiving, storing and transmitting significant quantities of water. Usually described by whether they consist of sedimentary deposits (sand and gravel) or fractured rock. Aquifer types include unconfined, confined and artesian.
Biodiversity	The variety of organisms, including species themselves, genetic diversity and the assemblages they form (communities and ecosystems). Sometimes includes the variety of ecological processes within those communities and ecosystems. Biodiversity has two key aspects: its intrinsic value at the genetic, individual species, and species assemblages levels; and ·its functional value at the ecosystem level. Two different species assemblages may have different intrinsic values but may still have the same functional value in terms of the part they play in maintaining ecosystem processes.
Conservation	The management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations, while maintaining its potential to meet the needs and aspirations of future generations. Thus conservation is the positive, embracing, preservation, maintenance, sustainable utilisation, restoration and enhancement of the natural environment.
Dissolved oxygen (DO)	The concentration of oxygen dissolved in water or effluent, normally measured in milligrams per litre (mg/L).
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of those systems.
Ecological water requirements (EWR)	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 the specific environment in which they live and with which they also interact, e.g. lake, to include all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Environment	Living things, their physical, biological and social surroundings, and interactions between all of these.
Environmental water provisions (EWP)	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 meet in part or in full the ecological water requirements.
Evaporation	Loss of water from the water surface or from the soil surface by vaporisation due to solar radiation.
Evapotranspiration	The combined loss of water by evaporation and transpiration. It includes water evaporated from the soil surface and water transpired by plants.
Gigalitre (GL)	A commonly used term to measure large volumes of water, equal to 1 billion litres, 1 million cubic metres or 1 million kilolitres (kL).
Groundwater	Water found under the land surface which occupies the pores and crevices of soil or rock.
Groundwater area	An area proclaimed under the *Rights in Water and Irrigation Act 1914* in which private groundwater abstraction is licensed.
Groundwater availability	The annual amount of groundwater available for abstraction, equal to the allocation limit minus any licensed entitlements.
GWhrs/yr	Gigawatts hours per year; the amount of (electrical) energy (generated or supplied) over a 12 month period.
Hectare (ha)	Hectare-10,000 square metres or 2.47 acres.
Kilolitre (kL)	1 Kilolitre= 1,000 litres, 1 cubic metre or 220 gallons.
Levee	An artificial embankment or wall built to exclude flood waters, or a natural formation adjacent to a waterway built by the deposition of silt from floodwaters.
Licence	An authority to carry out an activity, usually issued under the powers of a particular Act of a parliament. Carrying out the activity without a licence where one is required is illegal and an offence against the Act.
m AHD	Australian Height Datum – height in metres above Mean Sea Level + 0.026 m at Fremantle.

m^3/sec	Cubic metres per second.
Megalitre (ML)	Unit of (water) volume; one million litres, a thousand kilolitres or a thousand cubic metres.
Mt/yr	Million tonnes per year.
MW	Megawatts; a measure of power or rate of (electrical) energy production
Policy	A definite course of action adopted as expedient or from other considerations.
ppt	Parts per thousands, same equivalent as grams/litres.
Precautionary principle	Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason to postpone measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by: careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and an assessment of the risk-weighted consequences of various options. This provides an approach for considering the environmental impacts of a proposal on biodiversity values where there is a lack of knowledge and lack of scientific certainty. A useful methodology for applying the precautionary principle is that of Deville and Harding (1997).
Recharge area	An area through which water from a groundwater catchment percolates to replenish (recharge) an aquifer. An unconfined aquifer is recharged by rainfall throughout its distribution. Confined aquifers are recharged in specific areas where water leaks from overlying aquifers, or where the aquifer rises to meet the surface. Recharge of confined or artesian aquifers is often at some distance 'up flow' from points of extraction and discharge.
Salinity	The measure of total soluble (or dissolved) salt, i.e. mineral constituents in water. Water resources are classified on the basis of salinity in terms of Total Soluble Salts (TSS) or Total Dissolved Salts (TDS). TSS and TDS are measured by different processes, but for most purposes they can be read as the same thing. Measurements are usually in milligrams per litre (mg/L) or parts per thousand (ppt). Measurements in ppt can be converted to mg/L by multiplying by 1,000, e.g. seawater is approximately 35 ppt or 35,000 mg/L TSS. Salinity is also often expressed as electrical conductivity, measured by an electronic probe (conductivity meter). Water resources are classified as fresh, marginal, brackish or saline on the basis of salinity.
Social water requirements	Elements of the water regime that are identified to meet social (including cultural) values.

Stage 1 areas	The irrigation farmland areas serviced by the Stage 1 infrastructure of the Ord River Irrigation Project. Includes the areas supplied by the OIC (the M1 Channel Supply Area, the Packsaddle Pump Station Supply Area and the proposed Green Location development) and self supply areas (around Lake Kununurra), and land adjacent to the Ord River for the first 15 km downstream of the Diversion Dam.
Stage 1 (infrastructure)	All water related infrastructure that stores, diverts or transports water from the Ord River or drains water from farmland in the Ord Irrigation District, existing at September 2004. See also footnote on page 1.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Sustainability	Measure at the extent to which the needs of current and future generations are met through integration of environmental protection, social advancement and economic prosperity.
Sustainable yield	The limit on potentially divertible water available from a source is determined after taking account of "in-stream" values and making provision for environmental water needs, so that water extraction does not cause lowering of the watertable, intrusion of more saline water or environmental damage. The level of extraction measured over a specified planning timeframe that should not be exceeded to protect the higher value social, environmental and economic uses associated with the aquifer.
Water conservation	The management of water use to achieve and maintain an appropriate level of water use efficiency.
Water-dependent ecosystems	Those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of water resources, including flowing or standing water and water within groundwater aquifers.
Water efficiency	The minimisation of water use through adoption of best management practices.
Water entitlement	The quantity of water that a person is entitled to take on an annual basis as specified on a licence held by that person, and issued under the licensing powers of the *Rights in Water and Irrigation Act 1914*.
Water services provider licence	A licence issued under the provisions of the *Water Services Licensing Act 1995,* by the Economic Regulation Authority.
Water licence	A licence issued under the licensing provisions of the *Rights in Water and Irrigation Act 1914.*

Water resources	Water in the landscape (above and below ground) with current or potential value to ecosystems and the community.
Water regime	A description of the variation of flow rate in surface water or water level over time; it may also include a description of water quality.
Watercourse	A river, stream or creek in which water flows in a natural channel, whether permanently or intermittently.
Watertable	The saturated level of the unconfined groundwater. Wetlands in low-lying areas are often seasonal or permanent surface expressions of the watertable.
Well	A hole dug or drilled into an aquifer to monitor or abstract groundwater.
Wetland	Wetlands are areas that are permanently, seasonally or intermittently waterlogged or inundated with water that may be fresh, saline, flowing or static, including areas of marine water the depth of which at low tide does not exceed 6 metres. In WA, the term 'wetland' is commonly used to describe that subgroup of non-marine wetlands that are in basin or flat form (such as lakes, sumplands, damplands and palusplain), with the term 'waterways' more commonly used to describe those occurring in channel form (such as rivers and streams).

Most definitions have been taken from the Department of Water's glossary located at http://portal.water.wa.gov.au/portal/page/portal/dow. The remainder were defined specifically for the purpose of this plan.

Contributors

This report was prepared by staff of the Department of Water, from the Water Allocation Planning Branch, Division of Water Resource Use. Assistance was provided by staff from the Water Resources Assessment Branch, Water Resource Management Division and the Kimberley Region, Regional Business Operations Division.

Mr Ian Loh, Program Manager, Water Allocation Planning, was the primary author of the plan. Reservoir modelling and hydrology studies were carried out by *Simon Rodgers*, Environmental Engineer from Water Resources Assessment Branch. *Leith Bowyer*, as Manager of the Department's Kimberley Office, provided regional input and coordinated regional support during the plan's development. Ecological research and investigations and advice from the Scientific Panel were co-ordinated by *Paula Deegan, Kerry Trayler and Mike Braimbridge* from the Department's Environmental Water Planning Section, at different stages of the plan's development.

Scientific Panel members that provided advice on the ecology of the lower Ord River include the following:

Name / Affiliation	**Expertise**
Prof. Peter Davies, *University of WA*	Ecological processes
Dr Ray Froend, *Edith Cowan University*	Aquatic and riparian vegetation
Mr Gordon Graham, *Dept of Environment & Conservation*	Threatened, endangered species
Dr Stuart Halse, *Dept of Environment & Conservation*	Invertebrate and waterbird ecology
Dr Neil Loneragan, *CSIRO*	Estuarine processes
Dr Noel Morrissy *(representing Fisheries WA)*	Fish species
Mr John Ruprecht, *Dept of Water*	Hydrology
Dr Tony Start, *Dept of Environment & Conservation*	Aquatic and riparian vegetation
Dr Andrew Storey, *University of WA*	Ecology of fish assemblages
Dr Karl-Heinz Wyrwoll, *University of WA*	Channel dynamics and sediments
Dr Clare Taylor, *Dept of Environment & Heritage*	Australian Government NRM Facilitator - Rivercare/Water

Where to from here?

The Ord River Water Management Plan provides sufficient water to supply irrigation demand in the Western Australian portion of the M2 Supply Area and the Mantinea Flats and Carlton Plains areas, downstream of House Roof Hill. However, additional work is required to incorporate recent improvements in knowledge of the hydrology and ecology of the lower Ord River and resolve the competition between hydro-power generation and further allocations to irrigation. Specifically, the conditions under which additional water can be made available for use in the Northern Territory portion of the M2 Supply Area need to be determined.

Work is well underway to enable the current plan to be updated. A comprehensive level assessment of ecological water requirements for the lower Ord River is nearing completion and is expected to be finalised by early 2007. Streamflow data to 2004/5 has been analysed and used to update estimates of flows from the Ord River Catchment over the period between 1906/7 and 2004/5.

The updated hydrology and new EWR for the lower Ord River will be used, in conjunction with the sustainable diversion limits of the current plan, to assess the licence application for the first phase of M2 Supply Area development. Under the provisions of the *RIWI Act* applicants are required to advertise their licence application. Reservoir simulations will be repeated, using updated information, to establish compatible water release rules for the Ord River Dam Hydro-power Station with the new licence. As part of the licence assessment the Department will address input received from stakeholders and the community on the application and the current plan, and will prepare and release a report on the proposed licence conditions and power station water release rules, documenting the way water is to be managed in the M2 Supply Area under phased development. The report will also provide input to the setting of final environmental management conditions on the development, under the EP and EPBC Acts.

Resolution of the competition between additional water for irrigation (above the initial 400 GL/yr of the current plan) and hydro-power generation is required before the NT portion of the M2 Supply Area can proceed. This will require input from the key stakeholders and the community, and further reservoir simulations of allocation options, to refine the environmental water provisions of this plan and establish new sustainable diversion limits from the Ord River . Preparation of a replacement plan with these features are not expected to commence before 2009.

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