CHAPTER 12

Allocating for the Future of the Lower Ord River: Balancing Ecological, Social, Cultural, and Consumptive Water Requirements

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INTRODUCTION

The Ord River, in the east Kimberley region of Western Australia, is one of the state's major river systems. It is around 650 kilometres long, with a catchment area of 46,100 square kilometres, and drains into the Cambridge Gulf near Wyndham (figure 12.1). Currently, it is impounded by two dams, which provide water for irrigated agriculture and for the generation of hydroelectric power. There are plans to more than double the area under irrigation, which could triple water demand. If this increased demand were to be met, it would mean a reduction in the amount of water for the environment. However, under current state and federal policy, the environment is considered a legitimate user of water, and must be allocated an appropriate amount of the available water resource to ensure identified and agreed ecological goals are met and managed.

The Water and Rivers Commission (now Department of Environment—see chapter 11, on the institutional framework for managing water resources in Western Australia) has responsibility, on behalf of the community, to share equitably the water resources of the Ord River between ecological needs, social expectations, and demands to consume water for economic benefit. Its challenge is to develop a

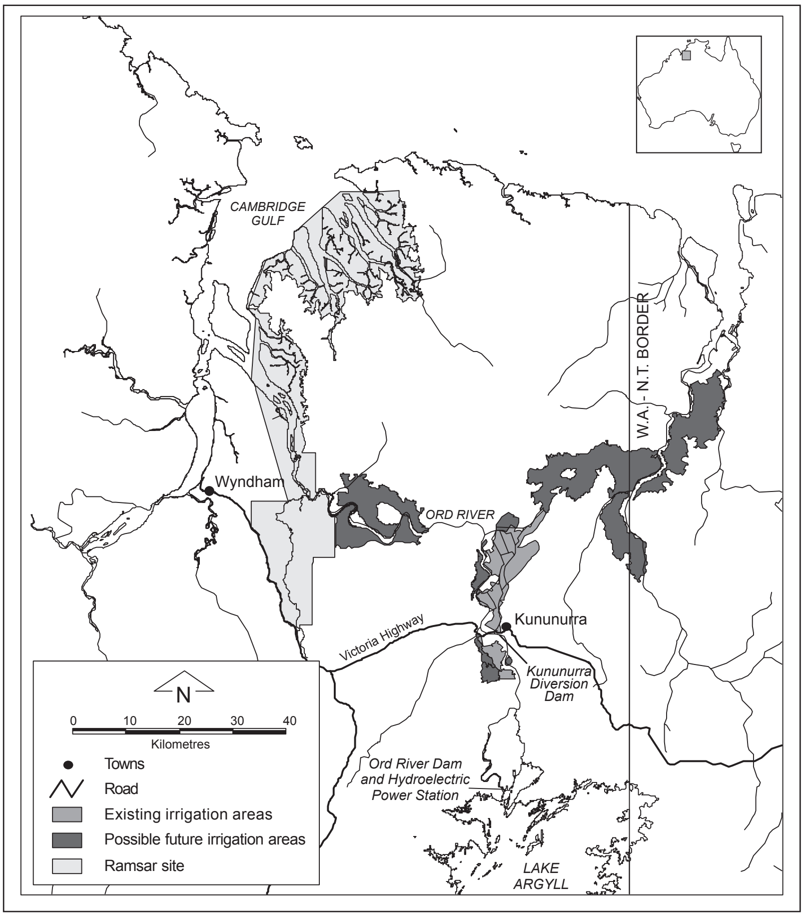

FIGURE 12.1: Location map of area downstream of the Ord River Dam

water allocation plan that satisfies all of these competing demands. This chapter describes the process for the determination of an interim Environmental Water Provision (EWP), with particular emphasis on the process, and some of the difficulties associated with determining the social and ecological water requirements. We also discuss the approach that should be applied in the short term to refine and finalise an EWP for the lower Ord River. This approach uses more accurate ecological and sociocultural information in conjunction with hydraulic survey and hydrological modelling, balanced against consumptive demands, within an open and accountable framework.

HISTORY OF DEVELOPMENT

The Ord River project, first mooted in the 1920s, has since attracted much criticism, particularly the reasons for development, which included: populating the north of Australia; providing protection from invasion from Asia; provision of a homeland for displaced Jews; pork-barrelling of electorates; and economic profits.[2] Following successful crop trials in the 1940s, the state government was convinced that an irrigation scheme would be viable,[3] and the Ord River Irrigation Area (ORIA) was created. Construction commenced with Stage 1 in 1963, which comprised the Kununurra Diversion Dam (KDD), irrigation infrastructure, and the township of Kununurra. Construction of Stage 2 followed in 1972, with the Ord River Dam (ORD) 55 kilometres upstream of the KDD, which formed Lake Argyle (surface area 74,000 hectares and storage of 10,700 gigalitres).[4] The next stage of development was in 1994, with the installation of a 30 megawatt hydroelectric power station into the ORD. Commissioned in 1996, the station has a licence to produce 210 gigawatt hours per annum, and generates power for the Argyle Diamond Mine (ADM) and local area (Kununurra and Wyndham).

Currently, the ORIA covers 13,000 hectares, and utilises 300 gigalitres of water per year.[5] To date, Stage 2 is only partially completed; however, it is proposed to extend Stage 2, to irrigate 30,000 hectares, requiring more than 1000 gigalitres per year.

CLIMATE AND HYDROLOGY

The climate of the region is important, as it influences the operation of the ORIA. The area has a semi-arid and arid monsoon climate, with pronounced wet (November to April) and dry seasons (May to October). Approximately 90 per cent of rainfall occurs during the 'wet', driven by monsoon depressions and tropical cyclones.[6] For the remainder of the year rainfall is infrequent, often with consecutive dry months. Average annual rainfall ranges from 780 mm near Kununurra to 450 mm in the south of the catchment, and net evaporation (2,000 mm/pa), exceeds rainfall in most months (figure 12.2).

Before impoundment, the Ord River experienced large wet season flows, and receded to isolated pools in the dry season.[7] Major floods occurred in 1959, 1960, 1966, 1971, 1980, 1993, and 2000, with the largest recorded flow of 30,800 cubic metres per second (m^3s^{-1}), recorded in 1956.[8]

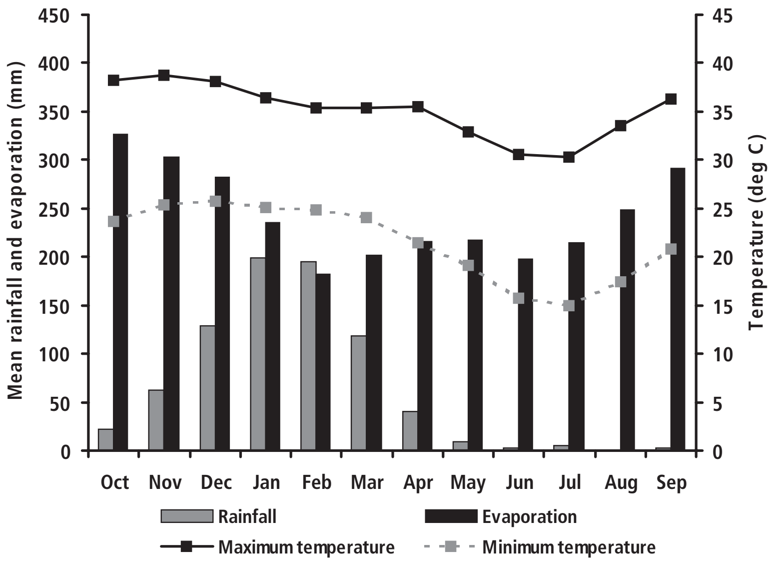

FIGURE 12.2: Mean monthly rainfall and evaporation, maximum and minimum temperatures, at Kimberley Research Station

The KDD and ORD have greatly modified the flow regime in the lower river, particularly reducing peak flows.[9] For example, maximum flows at the dam have not exceeded 1000 m^3s^{-1} since dam construction, although estimated inflows to the dam have exceeded 10,000 m^3s^{-1}.[10] Currently, the majority of seasonal variation in flows is provided by the unregulated Dunham River, which is less than 10 per cent of the Ord River catchment, but joins the Ord below the KDD.[11]

Regulation has also reduced floodplain inundation. Previously a one-in-ten-year flood caused substantial floodplain flooding, but now inundates only a small area of the historic floodplain, and the probability of a flood event inundating the lower floodplain has decreased from one in two years to one in 67 years.[12]

Although wet season flows have been reduced, flows are elevated much of the dry season because of releases for irrigation and hydropower and spillway flows.[13] Before 1996, releases from the ORD for irrigation, combined with irrigation return flows, resulted in average dry season flows of approximately 45 m^3s^{-1}. Currently, average flows are approximately 60 m^3s^{-1} reflecting increased releases for hydropower generation. The overall changes in flow regime have had a pronounced effect on ecological, social, and cultural values of the system, as discussed below.

FRAMEWORK FOR WATER ALLOCATION

Development of the ORIA occurred in a remote area, and before the current environmental, social, and cultural awareness. Today, increased awareness, supported by policy and legislation, has changed the way we look at large developments such as the ORIA.[14] In 1994, the Council of Australian Governments (COAG) adopted a framework to arrest widespread natural resource degradation, and address the economic, environmental, and social implications of water usage.[15] The environment was recognised as a legitimate user of water in legislation, and a set of National Principles for the Provision of Water for Ecosystems provided policy direction on how the specific issue of water for the environment should be dealt with in the context of general water allocation decisions.

In keeping with the national principles, the Water and Rivers Commission released the Environmental Water Provisions Policy for Western Australia, which describes an approach and principles for the protection of water-dependent ecosystems, while allowing for the management of water resources for their sustainable use and development to meet the needs of current and future users.[16]

Ecological water requirements (EWRs) are defined in the policy as the water regimes needed to maintain ecological values of water-dependent ecosystems at a low level of risk. EWRs are determined on the basis of the best scientific information available, and are the primary consideration in the determination of environmental water provisions (EWPs). Social values, which include domestic and stock water uses, Aboriginal and/or other Australian heritage, recreational pursuits, landscape, and aesthetic aspects, and educational or scientific aspects, are also considered as part of EWP determination.

Environmental water provisions are the water regimes that are provided as a result of the water allocation decision-making process (figure 12.3), taking into account ecological, social, and economic objectives and impacts. Evaluating EWPs and determining the water limit available for consumptive purposes can involve trade-offs. In undisturbed environments, the aim is to protect the existing 'natural' ecological values. In modified systems, consideration is given to environmental changes that have occurred, as well as the capacity for restoration. Therefore, determining the environmental objectives for systems such as the lower Ord River, requires 'value judgements' to be made. Where environmental risk is high, there is a statutory process of review of allocation decisions, which is made under the *Environmental Protection Act* 1986.

ALLOCATION PLAN FOR THE LOWER ORD RIVER

Increased pressures on the Ord water resource, as a result of the proposed Stage 2 expansion, necessitated the preparation of a Water Allocation Plan by the Water and Rivers Commission. In keeping with the EWP policy, the plan must determine ecological and sociocultural

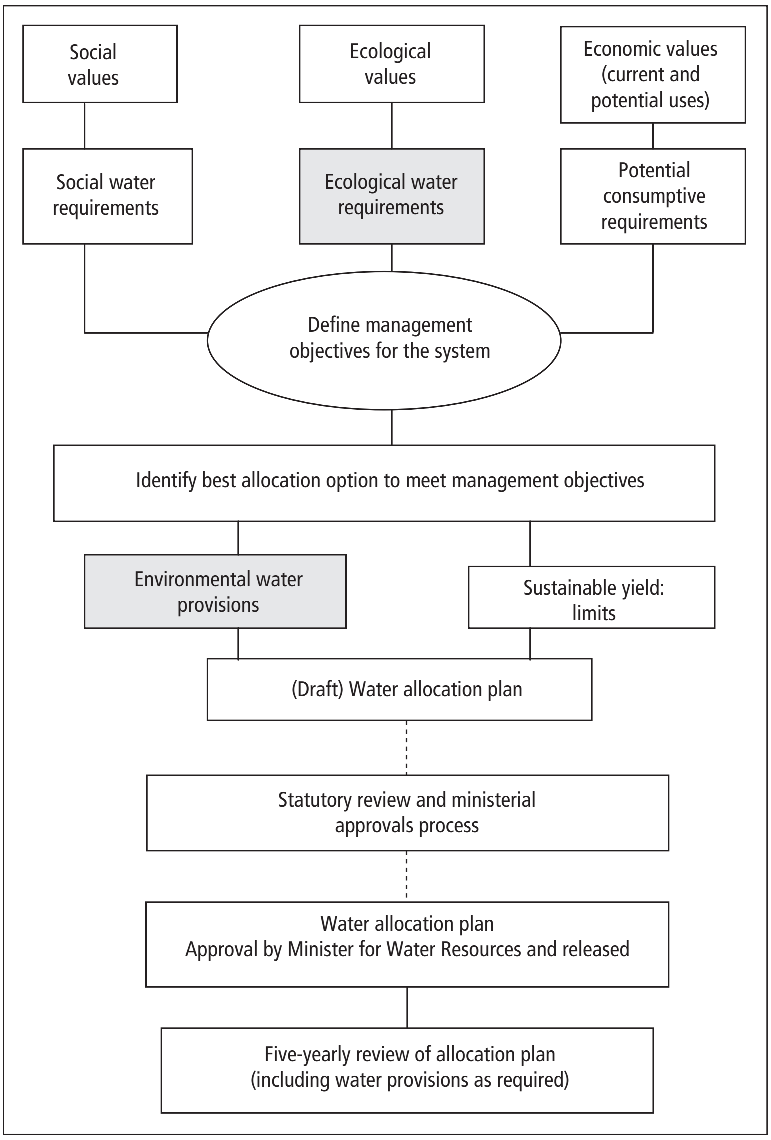

FIGURE 12.3: Framework for setting environmental water provisions (EWPs) in the Western Australian water allocation planning process (Waters and Rivers Commission)[17]

water requirements, as well as consumptive demands (figure 12.3). The paucity of information on the lower Ord River meant that documenting past and present ecological and social values was an important first step in the planning process.

Ecological values: past and present

Past values

Development of the Ord occurred in a remote part of the state, and in an era when environmental assessments were not required. As a result, there are no baseline biological studies for the system. However, some changes can be inferred from comparisons with adjacent unregulated systems, and also from photographic records.

A study of pre- and post-dam historical photographs of the Ord[18] showed a channel prior to impoundment that supported minimal vegetation compared with the current narrow, dense riparian zone. High-frequency flooding maintained the in-channel vegetation in an early successional stage that probably prevented the establishment of mature vegetation.[19]

Changes in the flow regime also resulted in changes in the morphology of the lower Ord River.[20] Reduced flooding resulted in sediment deposition, leading to the formation of point bars. This was promoted by submerged aquatic vegetation trapping and stabilising the sediments, which in turn allowed for channel encroachment by aquatic vegetation and colonisation by more substantial stands of vegetation. By inference, the channel prior to regulation would have been more uniform, without extensive point bars and beds of aquatic vegetation. Sediment effects are also observable in the estuary, where reduced flood magnitude, combined with tidal action, has resulted in siltation of the estuary.[21]

Prior to impoundment, fish such as barramundi (*Lates calcarifer*), ox-eye herring (*Megalops cyprinoides*), bull shark (*Carcharhinus leucas*), pony fish (*Leiognathus equulus*), mullet (*Liza alata*), tailed sole (*Aseraggodes klunzingeri*), scaley croaker (*Nibea squamosa*), freshwater sawfish (*Pristis microdon*), freshwater whipray (*Himantura chaophraya*), and spotted scat (*Scatophagus argus*) would have travelled further upstream, but are now limited by the dams to about one-quarter of their former range.[22]

Present values

Despite the acknowledged effects of the dams, the Ord River currently supports substantial ecological values. Lakes Kununurra and Argyle have provided reliable, permanent water in a seasonally arid region, and this has attracted large numbers and diversity of water birds, and allowed the establishment of large populations of freshwater crocodiles. As a result, the lakes are listed as wetlands of national and international importance.[23] In addition, the lower Ord River floodplain is also listed as a wetland of national and international importance, but on values documented in the post-regulation environment.

Studies of the fish fauna[24] reveal an estimated 39 species using the lower Ord River (table 12.1). Of these, three species are of specific conservation value, one species is listed as 'endangered' and 'critically endangered', and one species is listed as 'vulnerable'.[25]

A relatively high diversity of aquatic macroinvertebrates, with 171 taxa, has been recorded in the lower Ord River, and with certain taxa restricted in distribution to specific habitats.[26] Assessment of river health, based on macroinvertebrate assemblages, suggested that the Ord is moderately degraded in comparison to many other rivers in the Kimberley region.[27]

The Ord system also supports abundant and diverse waterbird populations.[33] During the wet season, most waterbirds prefer the floodplain wetlands; however, moderate-sized flocks of Magpie geese congregate along the channel during the dry, in addition to significant numbers of egrets, ducks, brolgas, storks, and other wading birds.

The riparian vegetation values of the Ord River and its floodplains have been relatively well studied.[34] The system now has a dense, narrow band of riparian vegetation that provides habitat, feeding areas, and food inputs in various forms. However, weeds are a significant problem, with infestations of species, such as leucaena (*Leucaena leucocephala*), date palms (*Phoenix dactylifera*), rubber tree (*Calotropis procera*), bellyache

TABLE 12.1: Fish species list for the Ord River.[28] Status shown as 1 Specific conservation value;[29] 2 'Endangered';[30] 3 'Critically endangered';[31] 4 'Vulnerable'.[32]

Scientific name	Common name	Family	Status
Ambassis macleayi	Macleay's Glassfish	Ambassidae	
Ambassis mulleri	Mueller's Glassfish	Ambassidae	
Amniataba percoides	Barred Grunter	Teraponidae	
Anguilla bicolour	Indian Short-finned Eel	Anguillidae	1
Arius graeffei	Lesser Salmon Catfish	Ariidae	
Arius leptaspis	Triangular Shield Catfish	Ariidae	
Arius midgleyi	Shovel-nosed Catfish	Ariidae	
Arramphus sclerolepis	Snub-nosed Garfish	Hemiramphidae	
Aseraggodes klunzingeri	Tailed Sole	Soleidae	1
Carcharhinus leucas	Bull Shark	Carcharhinidae	
Craterocephalus stercusmuscarum	Fly-specked Hardyhead	Atherinidae	
Craterocephalus stramineus	Strawman, Blackmast	Atherinidae	1
Elops australis	Giant Herring	Elopidae	
Glossamia aprion	Mouth Almighty	Apogonidae	
Glossogobius giuris	Flathead Goby	Gobiide	
Goby sp.	Goby sp.	Gobiide	
Hephaestus jenkinsi	Jenkin's Grunter	Terapontidae	
Himantura chaophraya	Whipray	Dasyatidae	4
Hypseleotris compressa	Empire Gudgeon	Eleotridae	
Lates calcarifer	Barramundi	Centropomidae	
Leiognathus equulus	Common Ponyfish	Leiognathidae	
Leiopotherapon unicolor	Spangled Perch	Terapontidae	
Liza alata	Mullet	Mugillidae	
Marilyna meraukensis	Merauke Toadfish	Tetraodontidae	
Megalops cyprinoides	Ox-eye Herring	Megalopidae	
Melanotaenia splendida australis	Australian Rainbowfish	Melanotaeniidae	
Nematalosa erebi	Bony Bream	Clupeidae	
Neosilurus hyrtlii	Hyrtl's Tandan	Plotosidae	
Nibea squamosa	Scaly Croaker	Sciaenidae	
Parambassis gulliveri	Giant Glassfish	Ambassidae	1
Plotosid sp. 1	Eel-tailed catfish	Plotosidae	
Plotosid sp. 2	Eel-tailed catfish	Plotosidae	
Pristis microdon	Freshwater Sawfish	Pristidae	2, 3
Scatophagus argus	Spotted Scat	Scatophagidae	
Sea mullet	unidentified specimen	Mugillidae	
Strongylura krefftii	Freshwater Longtom	Belonidae	
Syncomistes butleri	Butler's Grunter	Terapontidae	
Thryssa sp.	Anchovie sp.	Engraulidae	
Toxotes chatareus	Seven-spot Archerfish	Toxotidae	

bush (*Jatropha glossypifolia*), parkinsonia (*Parkinsonia aculeata*), climbing vine (*Clitoria ternatea*), and the Noogoora Burr (*Xanthium occidentale*).[35]

Sociocultural values

Past values

Indigenous peoples have occupied Australia for at least 40,000 years.[36] Archaeological evidence at Miriwun rock shelter and Monsmont, both now inundated by Lake Argyle, revealed a diversity of riverine and terrestrial food remains, with abundant and variable stone artefacts.[37] Similarly, surveys of the lower Ord River Ramsar site recorded 18 Aboriginal sites, including skeletal remains, burial sites, artefact scatters, mythological sites, quarries, paintings, ceremonial areas, and grinding/grooves, all of which supported past use of this floodplain area.[38]

Biographies of Muriuwung and Gajerrong people provide evidence for past Indigenous use of the Ord River.[39] For example, the floodplain provided food, particularly waterbirds, such as jabiru, pelican, flying fox, white crane, 'black divers', magpie goose, burdekin duck, black swan, and 'black and yellow ducks' (presumed to be whistling duck). Freshwater turtles and freshwater crocodiles were collected from waterholes, and emu hunted on the black soil plains. Many specific locations were also named as significant, such as Gobuama, and Yiralalam close to Kununurra, where bamboo was cut, and kangaroos and crocodiles collected respectively. On the lower Ord River, specific waterholes that were good for fishing were recounted. As well as hunting and camping sites, there are a number of locations on the Ord River that have been important for 'Dreamtime' stories (such as House Roof Hill, Bolgumirri and Adolphus Island, and Burrunungun), and specific wetland-dependent animals that appeared in stories; for example, brolgas (*Gurrandalang*), jabiru (*Dariimbagang*), and white crane (*Djalarrang*). More recently, Indigenous names have been documented for locations along the lower Ord River (table 12.2), each associated with a Dreamtime story, aspect of Aboriginal law, or culturally significant activity. Essentially, the presence of named locations indicates a previous close association with the river.

The seasonal rhythm of wet and dry, and the flooding of the river and floodplain, provided important predictable environmental triggers for cultural practice, movement, resource availability, and understanding.[40] The stretch of the Ord River between Carlton Hill Station, Ivanhoe Station, and Argyle Station (now inundated) used to be well traversed, and the river and its tributaries provided fishing and hunting grounds, in addition to a wide range of plant foods.[41] Aboriginal people travelled extensively during the dry seasons, crossing the river at locations where it was dry or divided by rocky bars.[42]

Some of the greatest losses of Aboriginal cultural values occurred with the construction of the dams and associated flooding, with losses including significant sites, graves, and areas of economic, cultural, and social value.[43] The construction of the ORD, and subsequent creation of Lake Argyle, destroyed numerous Aboriginal sites, and ended human occupation of an area that had extended from the last glacial maximum to the present.[44] The KDD was built on an important cultural site known as *Darram* (Bandicoot Bar). In Aboriginal mythology, the rocky pool was formed by women, who, in the Dreamtime, attempted to trap barramundi with rolls of spinifex. When the fish leapt to avoid the trap, the spinifex rolls turned into the rocky bars on which the dam is now constructed.[45]

Before development of the ORIA, the area only supported a small European population. The main social values based on the river were recreational activities, such as barbecues and picnics, fishing, and swimming at specific waterholes. In the dry season, some waterholes provided water for homesteads, and crossings for stock would have been important, as would have been Ivanhoe Crossing, as the main route to the Northern Territory. Floodplain grasslands, such as Parry Lagoons, would have provided good pasture.[46]

Present values

Although development in the Ord has had a negative impact on the local Aboriginal community, the land retains its cultural meaning and importance, and Aboriginal people still have strong links to the land and water, and retain responsibility for their country and its values.[47]

TABLE 12.2: Aboriginal named places along the Lower Ord River, with their closest location having a European name (from a map compiled by the Water and Rivers Commission and the Mirima Language Centre, in conjunction with the Shire of Wyndham–East Kimberley, Ord Land and Water, Department of Agriculture, CALM, Department of Fisheries, and the Recreational Fishing Advisory Committee).

Traditional name	Closest European named site
Darram	Bandicoot Bar (KDD)
Mirima	Mount Cecil
Thegoowiyeng	Kellys Knob
Nawale Warrim Moorrem	Abney Hill
Dengawiyem	Bandicoot Range
Migime	
Berranggoolnyim	
Jalinem	Fords Beach
Jirrinyngalem	Ivanhoe Crossing
Moorerreng	
Jilberriny	Ord Station Billabong
Jaboorrwarri Dawang	Buttons Crossing
Nganalang	
Ngamoowalem	Ivanhoe Range
Bandaba	Valentine Spring
Jaying	Tessie Creek
Mayiba	Middle Springs
Thegooyeng	Black Rock Falls
Ngoorrinybe	Buttons Gap
Gerloowerr-Gerring	
Darrareba	Tarrara Bar
Mijiyingarri	Sandy Beach
Winyba	Shale Bar
Jigoomirri	False House Roof Hill
Moolanba	Carlton Hill
Boorlgoomirri	House Roof Hill
Belawarroo	Carlton Crossing
Goolalawa	Goose Hill
Galawa	
Man-Ngala	
Mindilmirri	The Rocks

Aboriginal people continue to make use of the river, and use their traditional knowledge to gather vegetable foods and hunt animals.[48] They also use the riverbanks for hunting goannas, turtles, and wallabies, and fish the spillway of the KDD and other parts of the river. Cultural activities occur in close association with the river, which remains central to their society and worldview, in much the same way as the adjacent Fitzroy River does to the people associated with it.[49]

Traditional owners have a strong sense of responsibility for their country, and the values it contains. They have expressed concern over the current condition of the Dunham and Ord Rivers and associated floodplain billabongs.[50] They are concerned about water quality and the health of these systems, and are frustrated by riverine accessibility issues, caused in part by fencing, but also increased cumbungi (*Typha* bulrush) growth.

Since development, many social values have developed on the lower Ord River. The power station, agriculture and horticulture, and commercial fisheries in Lake Argyle provide employment. Ecotourism is also a major asset, with boat tours, wildlife spotting, fishing, house boats, and float-plane tours on Lakes Argyle and Kununurra. Other activities include bird watching at Parry Lagoons, and fishing camps and cultural tours on the lower Ord River.[51]

Lake Kununurra is used for water sports, such as water skiing, sailing, and the annual dam-to-dam speedboat race, and real estate along the lake is increasingly valuable. Significant historic sites include Ivanhoe Station, Telegraph Hill at Marlgu Lagoon, the Argyle Downs homestead, and Ivanhoe Crossing, and the river provides potential for environmental education.

ALLOCATING WATER TO PROTECT ECOLOGICAL AND SOCIO-CULTURAL VALUES

Accounting for altered environmental values

When the Water and Rivers Commission (WRC) first undertook the development of its interim water allocation plan for the Lower Ord River, the approach taken in determining the environmental provision was a rule-of-thumb twentieth percentile of the natural flows. Little ecological data was available to support a more sophisticated approach. A volume of 600 gigalitres per year (Glyr^{-1}) was to be released to meet the environmental provision. In keeping with the precautionary principle, approximately 265 Gl remained unallocated. Priority for this water was given to meet revised environmental provisions when adequate data on riverine ecology became available, and an additional dry season flow provision was foreshadowed to mitigate irrigation return.[52] Public comments on that 1999 draft water allocation plan considered that it did not adequately protect the environmental values that had arisen in the 30 years since regulation (table 12.3). The Environmental Protection Authority (EPA) recommended that WRC review the proposed environmental water provisions, and that maintenance of the riverine environmental values established since the construction of the ORD be the basis of that review. The EPA also recommended that WRC seek advice from a panel with expert knowledge of tropical river ecosystems, and undertake further community consultation. Subsequently, a Community Reference Group and a Scientific Panel were established to provide input towards establishing sociocultural and ecological water requirements, respectively.

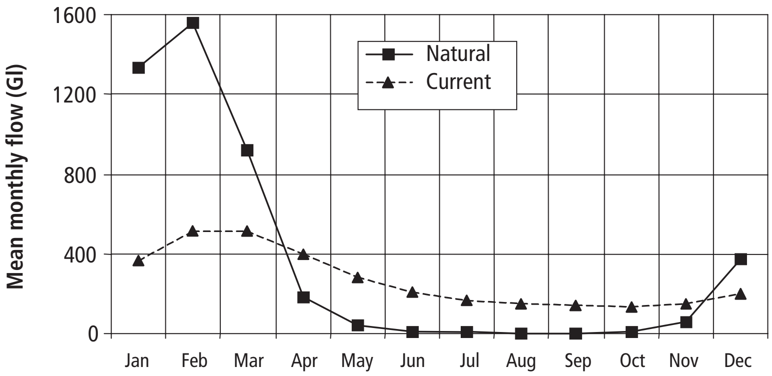

FIGURE 12.4: Current and natural flows in the lower Ord River (at Carlton Crossing)

Estimating ecological water requirements

The Scientific Panel identified important physical and biological attributes of the Ord River system, and the water regime upon which those attributes were dependent. The panel also described each attribute in terms of the pre- and post-regulation hydrology, and potential risks associated with reductions in the current flow regimes (table 12.3).

The members of the panel emphasised the limitations imposed by the minimal ecological data. Within that constraint, they identified the maintenance of an adequate dry season flow as a key consideration in determining the ecological water requirements. They made a number of recommendations,[53] including that dry season water levels and flows should be maintained at current or possibly slightly lower levels; the level to which flows could be lowered would be dependent on an assessment of impacts on habitat and water quality; flows could be allowed to gradually decline towards the end of the dry season, but not to the extent where the river would recede to isolated pools; and, to maintain present ecological processes, and waterbird and aquatic invertebrate values of the Lower Ord floodplain, there should be no significant diminution in the existing frequency and size of flood events.

At the time, there were no quantitative data available directly linking water levels and ecological responses for the lower Ord River. Therefore the approach undertaken by the commission in determining ecological water requirements[54] was to determine changes in dry season wetted perimeter under different discharge levels, specifically measuring alterations in the proportion of deep (>1 m) and shallow (<1 m) water 'habitat'. Wetted perimeter was selected as being indicative of the area of channel available for fish and invertebrates. The selection of depth zones was not based on knowledge of species habitat requirements, but rather an assumption that shallow, slow-flowing areas would support different species and age-class assemblages than deeper, faster-flowing areas.

Channel cross-sections within the three distinct geomorphological reaches were surveyed below the KDD in June 2000. Wetted perimeter was measured as the width of the channel underwater at each transect.

TABLE 12.3: Summary of potential impacts of future changes to the water regime

Attribute	Likely impact of potential flow modifications (compared with the current scenario)	Key considerations
Channel dynamics and sedimentation	Probably insignificant compared to impact of dams, but may exacerbate channel narrowing and pool infilling	Assumptions based on limited investigations. Impacts of 1999–2000 wet season floods need assessment and determination of potential for active channel management. Relationship between deposition and encroachment of vegetation needs further clarification. Catchment and floodplain management should be considered.
Aquatic and riparian vegetation	Probably benign if dry season flows do not become 'no flow', but a shift in communities is likely. Potential for further encroachment of emergent macrophytes into shallower parts of channel will increase the rate of channel infill.	Relationship between sedimentation and vegetation establishment needs to be confirmed. Increased nutrient concentrations in lower flows could also increase macrophyte growth.
Mangroves	Impacts likely to be benign	
Invertebrates	Low dry season flows could increase species diversity, but loss of wetted area and shallow instream habitat could reduce abundance	Relationship between discharge levels and wetted area–shallow instream habitat areas needs to be confirmed to allow assessment of significance of lower dry season flows.
Fish assemblages	Potentially significant. Less wetted area will mean reduced habitat for fish. Proportion of channel covered by macrophytes/epiphytes may increase—high respiration may result in anoxia and fish kills if there are no flow periods. Dry season no flow periods with isolated pools would be potentially catastrophic for fish.	Relationship between discharge levels and wetted area/shallow instream habitat areas needs to be confirmed to allow assessment of significance of lower dry season flows.
Waterbirds	Potentially benign if flood frequency and area of inundation remain unchanged. Rates of change of water levels in Lakes Argyle and Lake Kununurra need to be maintained near current.	Management of water levels in Lake Kununurra should be reviewed to meet downstream management requirements but protect Jacana nesting requirements.

Attribute	Likely impact of potential flow modifications (compared with the current scenario)	Key considerations
Crocodiles	Likely to be benign.	Impact on nesting site availability may need review
River processes	Depends on impact of reduced dry season flows on habitat and energy inputs. Sufficient flows are required to maintain pool levels that can 'buffer' the effects of high oxygen consumption by plants and animals.	Relationship between dry season water level and habitat needs better definition. Relative importance of shallow margins and of deeper water needs to be determined.
Water quality	Potentially highly significant. Lower flows could increase concentrations if nutrient and pesticide inputs remain unchanged. High sediment levels create a sink for nutrients that may be released as sediments are exposed by low water. Isolated pools with no flow periods potentially catastrophic.	The level of low flows which may be acceptable—while maintaining water quality—needs to be determined. The potential for mitigation through catchment management needs to be addressed.

The potential for risk to the riverine environment was estimated by determining wetted perimeter, and comparing a range of potential future flow regimes against a representative 'minimum' dry season flow rate for the historic period (1971–2000). A flow of 50 m^3s^{-1} downstream of the KDD was adopted as the basis for comparison. This was determined from the median flow over the driest five months of the year during the historic period. Predicted changes in wetted perimeter (>20 per cent) along three separate sections of the river, under a range of flow scenarios, are summarised in figure 12.5. As would be expected, the greater the reduction in minimum flow rates, the greater the change in wetted perimeter. The greatest risks to the modified river and habitat are on channel sections between Tarrara Bar and the start of the tidal influence. However, once flows drop below 40 m^3s^{-1}, there is a marked increase in the number of sections that change 'significantly' above Tarrara Bar. There was very little difference in wetted perimeter

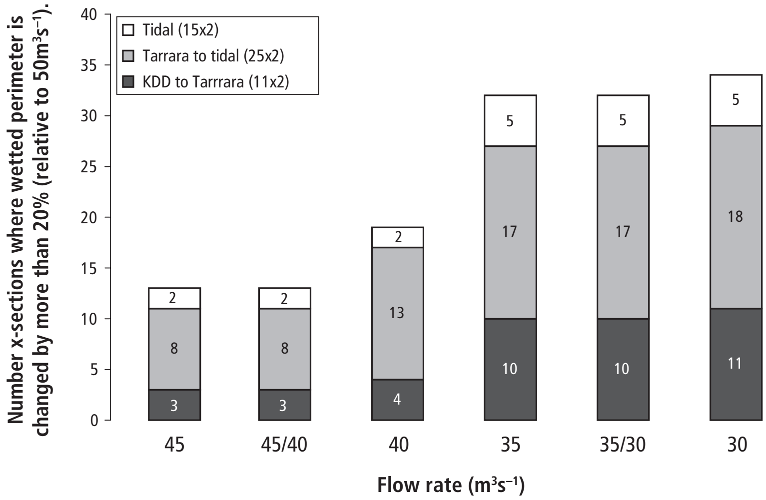

FIGURE 12.5: Changes (>20 per cent) in wetted perimeter across three distinct geomorphological zones of the lower Ord River. Note that flow rate described as 45–40 m^3s^{-1} refers to 45 m^3s^{-1} from the Kununurra Diversion Dam to 57.5 kilometres downstream, and 40 m^3s^{-1} below that point

outcomes between the maintenance of 45 m^3s^{-1} for all of the Lower Ord, or for 45 m^3s^{-1} from the KDD to the 57.5-kilometre point, and 40 m^3s^{-1} below that point. This is because the channel is generally a flattened 'U' shape downstream of the 57.5-kilometre point. It also becomes predominantly tidal from the 73-kilometre mark, and flow rates there will have less impact on wetted perimeter.

The commission concluded that the decrease in depth and wetted perimeter associated with the maintenance of a minimum flow rate of 45 m^3s^{-1} from the KDD to the 57.5-kilometre point and 40 m^3s^{-1} below that point was an acceptable estimate of the ecological water requirement. This was viewed as limiting the change to the dry season flows, and hence the risk of triggering adverse dry season ecological impacts described by the Scientific Panel. This estimate of the ecological water requirement was, however, viewed as an interim measure. The absence of sound quantitative data (other than hydrological information) on which to base the development of ecological water requirements, and the assumptions made in interpreting the wetted perimeter results, meant that the estimates of ecological risk could only be regarded as preliminary.

Estimating sociocultural values and water requirements

A Community Reference Panel was established in June 2000 to assist in identifying the social values of the Lower Ord River. Representation was drawn from a broad range of stakeholders (see table 12.4), and comprised local government, farming, environment, tourism, recreation, and Indigenous interests. The group expressed a range of views about the degree to which reduced flows would be acceptable. In general, there was strong similarity between the Community Reference Group recommendations and those of the Scientific Panel, in particular, the need to maintain dry season flows at a level that would avoid water-quality and other ecologically adverse impacts.

Community consultation was limited and driven by the desire to release a Revised Interim Water Allocation Plan in the shortest possible period. Further consultation was proposed to follow as part of the development of the final water allocation plan (then expected in 2005).

Description and mapping of Aboriginal sociocultural values, which might be affected by changes in the water regime, was attempted.[55] Although that study did not fully achieve its objectives, it did describe broad past and present values, and made clear the Aboriginal understanding and responsibility for the country, and their expectation for a role in management.

Studies to determine the contribution of tourism and recreational activities in the lower Ord River to the local economy estimated them at approximately $5 million per year, with benefits primarily derived from recreational fishing and charter activities and associated incremental tourism.[56] While this is far less than the contribution made by the irrigation industry, the local community views the recreation-based values, as well as the broader sociocultural values of the lower river, as very important, and is seeking to have these protected.

TABLE 12.4: Stakeholders identified for the Ord River, showing their primary interest(s).

	Interest			
Stakeholder	Ecological	Social	Cultural	Economic
Aboriginal Affairs Department	•		•	
Aboriginal Language Groups (Muriuwung/ Gajerrong)	•	•	•	•
Aboriginal Planning for Country Steering Committee	•		•	
Agriculture WA				•
Argyle Diamond Mine				•
ATSIC Regional Council	•		•	
Balanggarra Aboriginal Corporation	•		•	
Care of the Ord Valley Environment	•	•	•	
Community of Kununurra	•	•		
Conservation Council of WA	•	•	•	
CSIRO–Ord–Bonaparte Project	•	•	•	•
Dept. of Conservation and Land Management	•	•	•	•
Department of Environmental Protection	•			
Department of Resources Development				•
East Kimberley Recreational Fishery Advisory Commission	•	•		
Eco-tourist operators (e.g. Macka's Barra Camp, Ord River Tours, JJJ Tours, Ultimate Adventures Fishing)	•	•		•
Environment Australia (Dept. of Environment and Heritage)	•	•	•	
Environmental Protection Authority	•			
Environs Kimberley	•		•	
Fisheries WA	•			•
Kimberley Development Commission				•
Kimberley Land Council	•		•	
Kimberley Produce				•
Kimberley Specialists	•		•	
Kimberley Tourist Association	•	•		•

	Interest			
Stakeholder	Ecological	Social	Cultural	Economic
Kununurra Horticulture Producers Association		•		•
Kununurra Rate Payers Association		•		•
Kununurra Tourist Bureau	•	•		•
Land Conservation District Committee	•		•	
Local community (non-aligned)	•	•	•	•
Lower Ord Community Advisory Committee	•	•		
Lower Ord Management Committee	•	•		
Northern Land Council	•		•	
Ord Development Commission				•
Ord Development Council				•
Ord Hydro Pty Ltd				•
Ord Irrigation Cooperative				•
Ord Land and Water	•	•	•	•
Ord River Cucurbit Growers Group				•
Ord River Mango Growers Association				•
Ord River District Cooperative				•
ORIA Orchards				•
Research Institutes (CSIRO, UWA, Murdoch)	•		•	
Save Endangered East Kimberley Species	•			
Shire of Wyndham–East Kimberley		•		•
Southern Cross Aquaculture				•
Sugar Research and Development Corporation				•
Tourists	•	•		
Traditional landowners	•		•	
Water and Rivers Commission (Dept. of Environment)	•	•	•	•
Water Corporation		•		•
Western Australian Tourism Commission	•	•		•
World Wide Fund for Nature	•	•	•	

Consumptive requirements: the demand for water

Water allocation requests from existing irrigators and proponents of the development (as at November 2001) are listed in table 12.5. These are compared with the commission's estimates of reasonable needs, given the crops proposed, and responsible water use and management. Other demands in the region include water releases for hydropower sufficient to generate 210 $GwHr.yr^{-1}$.

In December 2001, the proposal to develop 30,500 hectares of sugar on the Weaber, Knox, and Keep River plains (M2 Sugar Project) was withdrawn. At that time, the Revised Interim Water Allocation Plan was approaching release. Trade-offs were expected where demand exceeded the amount of available water. The withdrawal delayed the release of the plan, and left the way open for a range of development options that might have different water needs. The plan, therefore, had to be redrafted.

Proposed environmental water provisions

The Revised Interim Water Allocation Plan will use estimates of ecological risk, together with hydrological analyses, water quality data, and information on sociocultural and economic values to provide the basis for determination of the environmental water provision. An interim and precautionary environmental provision, equal to the estimated

TABLE 12.5: Comparison of irrigation water requested and estimated needs as at November 2001.

Irrigation area	**Water requested (Gl/yr)**	**Commission's estimate of reasonable need (Gl/yr)**		
		Existing use	**Growth**	**Total**
Stage 1 Channel customers	365	238	95	333
Stage 1 Water-course pumpers	15	6	8	14
Proposed M2 Sugar project	710	—	692	692
Total	**1090**	**244**	**795**	**1039**

ecological water requirement, and based on a minimum dry season flow rate and wetted perimeter results, has been proposed. Reduced environmental provisions during extended periods of drought have been mooted, and some considerable effort has been applied to trial and model the effect that these lower flows might have on the environment. However, to date a decision on the acceptability or otherwise of the low flow under drought conditions has not been made public.

Annual instantaneous peak flows are expected to remain similar to that which currently occurs (figure 12.6). This reflects the importance to the post-regulation flood peaks of the largely unregulated Dunham River catchment, and the importance of ensuring that the flow regime of the Dunham River is not further altered.

TOWARDS AND BEYOND A REVISED INTERIM WATER ALLOCATION PLAN

The Revised Interim Plan is intended to protect the riverine ecological and social values associated with the modified post-regulation flow regime, and to provide conservative estimates of the amount of water

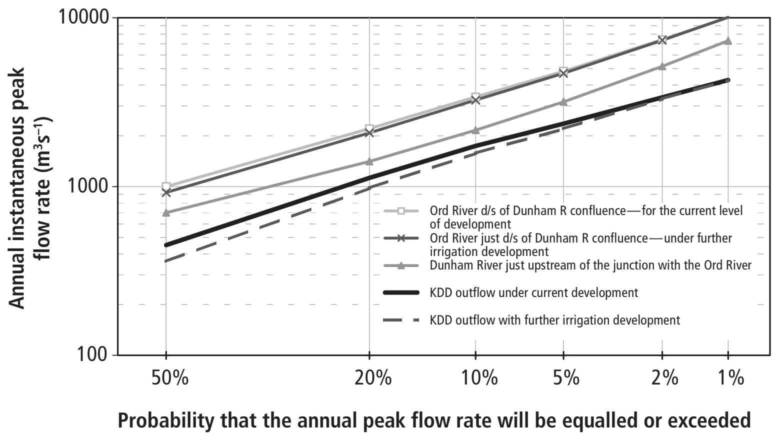

FIGURE 12.6: Annual flood frequency distributions for the lower Ord River under the current and expected future allocation scenario

available for consumptive demand. It was always intended that the Revised Interim Plan would be replaced with a 'final' plan within five years, based on new information available. Ironically, it has been over five years since the EPA initiated its development. There is an expectation that the available information will be used to refine estimates of ecological water requirements, and better define the magnitude and pattern of intra- and inter-annual variability.

While world sugar prices remain low, and there is no clear proponent for agricultural development in the Ord Stage 2 M2 area, there is an opportunity for the Department of Environment to move quickly beyond its Revised Interim Plan, and consolidate new environmental information into improved estimates of water required. Improved hydrologic modelling, combined with good hydraulic information and a better understanding of the ecology, should form the basis for replacing the interim water provision estimates in the short term (see table 12.6). There is also an opportunity for the department to engage with the community and determine, in a more quantitative manner,[57] the water requirements to protect sociocultural values. These would be fundamental building blocks towards an open and accountable process for determination of the amount of water to be provided to the environment, and sustainable limits for abstraction.

TABLE 12.6: Status of scientific projects aimed at informing ecological water requirements

Study area	Key information needed	Status
Riverine ecology and management	Fish and invertebrate habitat surveys	Complete
	Productivity and water flow regulation	Progress toward flow recommendations
	Water quality and aquatic biota responses to low flow rates	Study complete
	Riparian ecogeomorphology	Report pending
Estuarine studies	River–estuary project	Ongoing
Surface water hydrology	Updated estimates of likely future flows of the (unregulated) Ord River and its tributaries	Hydrologic investigation (WRC)
	Supporting river hydraulics and hydrology for ecological studies	Under way