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**Meeting Indigenous people's objectives in environmental flow assessments:
Case studies from an Australian multi-jurisdictional water sharing initiative.**

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Abstract

The multi-dimensional relationships that Indigenous peoples have with water are only recently gaining recognition in water policy and management activities. Although Australian water policy stipulates that the native title interests of Indigenous peoples and their social, cultural and spiritual objectives be included in water plans, improved rates of Indigenous access to water have been slow to eventuate, particularly in those regions where the water resource is fully developed or allocated. Experimentation in techniques and approaches to both identify and determine Indigenous water requirements will be needed if environmental assessment processes and water sharing plans are to explicitly account for Indigenous water values. Drawing on two multidisciplinary case studies conducted in Australia's Murray-Darling Basin, we engage Indigenous communities to (i) understand their values and explore the application of methods to derive water requirements to meet those values; (ii) assess the impact of alternative water planning scenarios designed to address over-allocation to irrigation; and (iii) define additional volumes of water and potential works needed to meet identified Indigenous requirements. We provide a framework where Indigenous values can be identified and certain water needs quantified and advance a methodology to integrate Indigenous social, cultural and environmental objectives into environmental flow assessments.

Keywords: cultural water values, environmental flows, Indigenous values, social assessment, Murray-Darling Basin.

1.0 Introduction

Societal values and attitudes relating to water use and management have undergone substantial change over recent decades in response to environmental degradation from resource development, over-allocation, land use change and pollution. Governments and water agencies have become more receptive to calls for new models of knowledge generation to integrate decision making, address social complexity and enable wider democracy in environmental management (Pahl-Wostl et al., 2011; Norman and Bakker, 2009; Godden, 2005).

Changes in community attitudes to river and water management are reflected to a very large extent in Australia's current national program of water reform (Connell et al., 2005). The aim of national policy includes establishing clear pathways to return all surface and groundwater systems to environmentally sustainable levels of extraction. Signatory governments must take a 'whole-of system approach', agree to the level of modification appropriate for a given hydrological system and prioritise provision of water sufficient to stabilise environmental conditions and resource security (Connell and Grafton, 2008: 70). In those parts of Australia where rivers and wetlands have experienced severe ecological degradation from reduced inflows and extended drought, such as the Murray-Darling Basin (MDB), the policy response has been to reallocate water from agricultural uses to improve the health and resilience of its aquatic ecosystems, whilst seeking to balance environmental, economic and social considerations (MDBA, 2012a; 2010; Bark et al., in review). Recovering water for the environment from agriculture is warranted in this region because over-allocation of water entitlements is estimated to be about 25% relative to total sustainable yield (National Water Commission, 2007).

A legal mandate to allocate water to the environment is integral to the transformation in Australian water policy. It is driving the development of techniques to assess and determine environmental flows across scales and the emergence of an environmental water governance system with institutional arrangements to acquire and manage environmental water under a multi-billion dollar program. In the MDB, the Commonwealth government is purchasing consumptive water rights from willing sellers to reallocate to river environments (Foerster, 2012). When the purchasing program is complete, the Commonwealth Environmental Water Holder will hold more than one-quarter of all water entitlements in the MDB (Connell, 2011). Substantial sums are also being invested in irrigation infrastructure to achieve further water savings.

The National Water Initiative (NWI) represents a further significant shift in water policy because, for the first time in the nation's history, it seeks to incorporate Indigenous rights, interests and values in water management (Jackson et al., 2012). The NWI requires jurisdictions to take into account native title interests, to assess and include Indigenous customary, social and spiritual objectives in water plans, and to engage with Indigenous communities in their development.

Although the requirements of the NWI and *Water Act 2007* provide an impetus to improve Indigenous access to water and participation in water management, governments across Australia have only just begun to formally recognize Indigenous peoples' relationships with water for spiritual, cultural and economic purposes. Progress towards meeting Indigenous claims and

expectations has been slow for a range of reasons (Tan and Jackson, 2013; Bark et al., 2012; NWC 2011; 2014) and there is insufficient appreciation from wider society of the negative social and cultural impacts of aquatic ecosystem degradation on Indigenous communities (Behrendt and Thompson, 2004; Jackson, 2006; Weir, 2009; 2011).

The (third) biennial assessment of national progress on water reform found that where assessments of Indigenous values have been made, they usually involved cursory desktop reviews (NWC, 2011; see also NWC, 2014). Finn and Jackson (2011) also note the prevalence of an assumption that biophysical assessment of environmental flows can adequately serve as a surrogate for a targeted mechanism or assessment process to meet Indigenous social, cultural or spiritual requirements, perceived to obviate the need for more rigorous assessments.

The number of Indigenous consultative groups and processes pertaining to water management has grown considerably in recent years. Nonetheless, ecologists, hydrologists and water resource managers face an outstanding challenge to use 'those engagement processes to more explicitly account for Indigenous water values and requirements in water planning' (NWC. 2011: 44). Meeting this important challenge will require a strong evidence base and experimentation in techniques and approaches to the identification and determination of Indigenous water requirements, alongside reforms to planning practice and policy frameworks (see for example, Jackson et al., 2014; Jackson and Barber, 2013; Mooney and Tan, 2012; Bark et al., in press).

To improve Indigenous access to water and environmental water governance, managers and Indigenous organisations require information that will enable them to: (i) assess the full range of

impacts of changes in water availability, and (ii) understand the benefits that Indigenous people might derive from improvements in environmental condition and participation in management institutions, as well as (iii) the benefits accruing to wider society from Indigenous management of natural resources such as water.

In Australia, the research need is arguably most acute in the MDB for two reasons. Firstly, the basin has experienced relatively severe ecological losses as a result of over-allocation of water and these pose a threat to Indigenous identity and well-being (Weir, 2009; 2011). Secondly, the imperative to achieve environmental sustainability across the basin is driving substantial reforms to water governance which have the potential to redress the historical exclusion of Indigenous interests, rights and values (Jackson, 2011). The multi-jurisdictional water sharing initiative (the Basin Plan), enacted to address over-allocation of water resources to irrigation and other consumptive uses, provides an impetus to integrate Indigenous objectives in environmental flow assessments and in environmental water management.

This paper describes the results from two multidisciplinary studies of Indigenous water values and benefits from re-allocating water to the environment in the state of New South Wales (see CSIRO, 2012; Maclean et al., 2012). The case studies focused on water dependent ecosystems that are of environmental and cultural significance to Indigenous land owners and are formally recognised by the wider Australian public for their heritage and conservation values. The paper contributes to two related areas of water policy that have been relatively neglected: assessing and accounting for social benefits from water (Syme et al., 2008) and, more specifically, including Indigenous or local knowledge and valuations in integrated environmental flow studies (Pahl-

Wostl et al., 2013; King and Brown, 2010; King et al., 1999; Lokgariwara et al., 2014; Tipa and Nelson, 2012).

The paper addresses a broad need identified by Syme et al. (2008) for methodologies that generate social and cultural information in a manner that can be incorporated into a systems view of sustainability within a catchment context. It achieves this by advancing methodologies designed to integrate social and environmental objectives within environmental flow assessments (EFAs); thereby fulfilling a wider role for environmental flows in the context of sustainable water resource management (Matthews et al., 2014). It employs a collaborative approach to water resource assessment and describes methods that rely on Indigenous input to improve the scope, legitimacy and fairness of water allocation processes. At each case study site, we engaged Indigenous communities to (i) understand their values and explore the application of methods to derive water requirements to meet these values; (ii) assess the impact of alternative water planning scenarios on these values; and (iii) define additional volumes of water and potential works needed to meet identified Indigenous requirements. We provide a framework where Indigenous values can be identified and their water needs quantified.

The paper is organised as follows. First, we situate the Australian problem in the context of international developments in integrated assessments of environmental flows, particularly efforts to address the social aspects of water use and its availability for local Indigenous communities. We then provide an overview of Indigenous water-related interests and describe the planning framework that is driving and shaping river restoration in the MDB. In the methods section we introduce the case studies and their context and outline our approach to data collection and

analysis. We then present and discuss findings from the assessment, outline remaining information needs and research questions, and provide suggestions for a more comprehensive approach for future application.

2.0 Integrating social factors into environmental flow assessments

Environmental flows are defined as the 'quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems' (Brisbane Declaration, 2007.). There is an extensive set of methodologies in use around the world to define water requirements of species and ecosystems, ranging from simple rule-based approaches, such as a fixed percentage of mean annual flow or seasonal flows (e.g. Tennant, 1976) to holistic methods that embrace the entire riverine ecosystem from source to terminus (Poff et al., 2010; for reviews, see Arthington, 2012; Tharme, 2003; Acreman and Dunbar, 2004). In Australia, a blend of expert opinion, field investigations and modelling are commonly used in EFAs (Arthington and Pusey, 2003; Tomlinson and Davis, 2010; Davies et al., 2014).

Social values, economic imperatives and cultural perspectives on human–nature relations all have a significant bearing on allocation frameworks, assessment methodologies and resulting water sharing decisions (see Matthews et al., 2014; Pahl-Wostl et al., 2013; Poff et al., 2010; van Wyk et al., 2006). There are however, few demonstrations of sociological assessment of environmental flow requirements (Pollard, 2000; 2002; Lokgariwar et al., 2014; Wilson and Carpenter, 1999). In the USA and Australia, efforts have been made to assess 'in-stream benefits' accrued to recreational anglers and boaters and the flow required to satisfy activities

reliant on water remaining in the watercourse (Cruse and Gillespie, 2008; Getches and Van de Wetering, 2005). Likewise in Africa and Asia, assessments have included regulating cultural and provisional services, as part of a broader cost benefit analysis (King and Brown, 2010). More recently, CSIRO conducted a study of ecosystem services in the MDB within the context of the Basin Plan (CSIRO, 2012). Despite these examples, environmental flow studies have rarely effectively incorporated Indigenous values.

Only tentative steps have been made to incorporate Indigenous values and subsistence water uses in flow allocation frameworks. Specific examples can be found in the USA (Balsom 1997), New Zealand (Tipa, 2009; Tipa and Nelson, 2012), Australia (CSIRO, 2012; Maclean, 2012; Jackson et al., 2014) and South Africa (Arthington et al., 2003; King and Brown, 2006). Finn and Jackson (2011) have previously demonstrated how the environmental flow assessment framework known as ELOHA (Ecological Limits of Hydrological Alteration; Poff et al., 2010) can be extended to incorporate Australian Indigenous values and objectives and traditional knowledge of flow-ecology relationships. ELOHA advocates the synthesis of existing hydrologic and ecological data to develop relationships between flow alteration and ecological responses in rivers of contrasting hydrological character. It emphasizes the importance of community values in structuring the assessment and selecting an appropriate environmental flow regime.

Indigenous values, which are consistently described as multi-dimensional (Finn and Jackson, 2011; Jackson and Barber, 2013) are at best a minor consideration in the water allocation systems that continue to represent rivers as a source of water and input to economic production (Tan and Jackson 2013; Tipa 2009; Weir, 2009). Water provides diverse goods and services (van

Wyk et al., 2006; Bark et al., in press) and it often constitutes environmental features of considerable importance to human (and non-human) relationships with place (Strang, 2013). The intangible values that Indigenous people regard as critical to their sense of identity, cultural practices, spiritual beliefs, customary management practices and livelihoods, are consistently raised as a challenge to the quantitative and competitive methods of resource allocation currently favoured in water governance reform programs. More tangible indirect water uses, such as the harvest and consumption of aquatic resources (e.g. fish) also deserve consideration in assessments of the costs of water resource development (Stoeckl et al., 2013; King et al., 2003; Welcomme et al., 2006). It is these issues that are of critical importance to more than thirty traditional owner groups who assert customary rights to land and waterscapes within the MDB (MDBC n.d., p. 3).

3.0 Indigenous interests in land and water in the Murray-Darling basin

The MDB covers just over 1 million square kilometers of mainland Australia, which is 40% of its land mass. Agriculture covers more than 80% of the region and generates approximately 40% of the gross value of Australian agricultural production, using around two-thirds of the nation's agricultural water consumption (Young and Chiew, 2011). It has a sizeable, culturally coherent and distinctive Indigenous population (Taylor and Biddle, 2004) numbering approximately 70,000 people (amounting to 3.5% of the total Basin population and approximately 15% of the nation's Indigenous population). Having provided an ecological foundation for Indigenous livelihoods for millennia (Humphries, 2007), its land and water systems are vested with religious and cultural significance (Weir, 2009).

In the belief systems of the Basin's forty-five traditional owner groups, water is a sacred and elemental source and symbol of life. Aquatic resources constitute a vital part of customary life-ways (Aboriginal & Torres Strait Islander Social Justice Commissioner, 2008). Aboriginal groups of the Basin use land and water resources in a variety of inter-related ways including for subsistence use of wild resources (food and medicines, arts and crafts), recreation, and cultural practices (Weir, 2009). Although colonization has greatly disrupted multifaceted relationships to land and water they remain an important dimension of Indigenous identities.

Significant barriers prevent or limit Indigenous people from accessing water and satisfying their natural resource management objectives (Jackson et al. 2010; Weir, 2009; Weir and Ross, 2007). These barriers are of a legal, administrative, economic, institutional and epistemological nature. Notwithstanding the many impediments, some Indigenous organisations are using licensed water in their repertoire of management activities, often for conservation purposes (Jackson and Langton, 2012), and many more want to see environmental water directed to places and features of value or significance to their local communities.

Recent changes to the Basin's river systems have eroded its capacity to meet Indigenous needs (Weir, 2009; Ward, 2009; Morgan et al., 2004). The literature contains many accounts of detrimental socio-economic impacts for Indigenous peoples arising from over-development of water resources and associated environmental impacts from the Millennium Drought (2001-09) (e.g. river regulation, seasonal changes to flows, salinity problems) (Jackson et al., 2010; Maclean et al., 2012). Negative psycho-social effects, particularly loss of control and inability to

access and holistically manage customary estates, exercise custodial authority and to prevent further ecological degradation are reported (Weir, 2009; Morgan et al., 2004).

As a result of severe environmental degradation, the *Water Act 2007* mandated the Murray-Darling Basin Authority (MDBA) to prepare a basin-wide plan to reduce limits on water diversions for irrigation. An annual average of 2,750 GL of water, or 20% of baseline average water diversions, is to be returned to the environment by 2019 with an additional 450 GL by 2024 (Commonwealth of Australia, 2012; MDBA 2011). In most catchments, the Sustainable Diversion Limits (SDLs) are lower than current levels of extraction, resulting in additional water for the environment. The expectation is that ecological improvement will be achieved by recovering water from willing sellers and from irrigation efficiencies and re-allocating it as environmental flows (Arthington, 2012).

The MDBA is required to assess the social and economic impacts of this intervention and in doing so have regard for the social, cultural, Indigenous and other public benefit issues. Consideration of Indigenous interests is one of many Basin Plan objectives alongside requirements to implement international agreements, conserve sites listed under the Ramsar Treaty for wetland conservation and meet the water needs of ecological assets.

4.0 Methods

4.1 Study Area

The study area comprises the New South Wales (NSW) catchments of the Edwards River and the Barwon River in the vicinity of Deniliquin and Brewarrina respectively (Figure 1). Two multidisciplinary studies were undertaken during 2012 with two Indigenous groups in these areas: the Wamba Wamba, whose customary estates include the Werai Forest on the Edward River (CSIRO, 2012) and the Ngemba, whose customary estates include the Barwon River channel and floodplain wetlands in the vicinity of Brewarrina (Maclean et al., 2012). The sites were selected as study sites for pragmatic reasons relating to the level of community interest in the research questions surrounding determination of Indigenous water requirements.

Figure 1. Map of the Murray Darling Basin showing case study sites at Brewarrina and Deniliquin



4.1.1 Wamba Wamba Case Study (Werai Forest, Edward-Wakool River)

The study of Wamba Wamba water interests at Deniliquin arose out of a larger study of the multiple benefits of water recovery in the MDB (CSIRO, 2012). That study, *inter alia*, trialed a method of estimating the potential benefits to the Indigenous community of the then proposed Sustainable Diversion Limit (SDL) of the Basin Plan. The Wamba Wamba were approached because they had documented and mapped their use and occupancy of the Werai State Forest. Wamba Wamba leaders also saw value in the potential for results to inform their own management strategies (for a discussion of the community's environmental governance aspirations, see Weir et al. (2013)). The Werai State Forest is part of the Murray complex of wetlands recognised under the Ramsar Treaty. The size of the forest is 11,915 hectares. Part of the forest (the Werai Reserve) was vested with the NSW Minister for Environment and Climate Change for transfer to Aboriginal ownership in 2010 (Weir et al., 2013). Plans are afoot to manage this area under the Commonwealth Government's Indigenous Protected Area Program (IPA), a Federal biodiversity and cultural heritage conservation program.

The vegetation community of the Werai forest is comprised of an extensive river red gum forest and woodland system, with some areas of black box (*Eucalyptus largiflorens*) and lignum (*Muehenbeckia florulenta*). The forest also has extensive common reed (*Phragmites australis*) in low-lying wetlands (CEWH, 2011). Reed bed areas are highly valued by the Wamba Wamba people. The forest provides extensive habitat and resources for a range of aquatic, amphibious and terrestrial fauna and contributes energy directly to the river in the form of dissolved organic carbon (Roberts and Marston, 2011). When inundated, the area provides significant nesting

habitat for waterbirds (CEWH, 2011). The streams in and around the Werai are important for fish recruitment and serve as a refuge during drought periods.

The forest has experienced changes in frequency and duration of flooding due to alterations to land use, river regulation through water storage and diversions, and construction of weirs, floodplain levees and a series of flow control structures or regulators (CEWH, 2011). The regulators have a direct influence, reducing the inundation of the low-lying wetlands (Green, 2001) and there is anecdotal information to suggest that river red gums are now dominating in areas that were previously characterized by aquatic vegetation (Regional Evaluation Group C, 2003). Similar change has occurred downstream at the Barmah-Millewa Forest (Bren, 1992). Prior to recent floods (2010-2011, 2011-2012) which extensively inundated the Werai Forest and initiated a colonial-nesting waterbird breeding event (CEWH, 2011), its condition was generally considered to be poor (Cunningham et al., 2009).

4.1.2 Ngemba Case Study (Barwon-Darling River, Brewarrina)

The Ngemba Aboriginal community is located in and around the townships on the banks of the Barwon-Darling River in north western NSW (Figure 1). In 2010, an Ngemba elder approached the authors to assist his community in its efforts to restore the health of water bodies of cultural significance, particularly the Mission Billabong (the Billabong; an oxbow lake that fills periodically during flood flows) and the nationally registered heritage fish traps at Brewarrina (see Maclean et al., 2012; Bark et al., in press). Prior to European settlement, the Billabong area was an important tribal meeting place (Woodfield, 2000; Jackson et al., 2010). Between 1876

and 1967 it was the site of the Brewarrina Aboriginal Mission and it is now listed on the NSW State Heritage Register (Australian Government, 2011). The Billabong provides habitat for endangered species, including the brolga (*Grus rubicunda*), the blue-billed duck (*Oxyura australia*), the freckled duck (*Stictonetta naevosa*) and the red-tailed black cockatoo (*Calyptorhynchus banksii*). It also has wetlands and open woodlands with vegetation communities made up of river red gum (*Eucalyptus camaldulensis*) and coolibah (*Eucalyptus coolabah*). The channel of the Barwon-Darling River also provides important habitat for fish species (CEWH, 2012).

Aboriginal control of the Billabong is partially achieved through ownership of a pastoral lease underlying a section of the adjacent Billabong (called 'Moonbi') and the management of another portion under the Indigenous Protected Area Program. A non-Indigenous pastoralist owns the remaining area of the Billabong. An Aboriginal organization holds a water license attached to the adjacent Moonbi pastoral lease.

4.2 Methodology

The two case studies differed slightly in scope and duration, however both sought an understanding of (i) local Indigenous values, water management objectives and water requirements, (ii) the relationship between Indigenous values and the hydrological regimes predicted under the proposed management arrangement to be established by the Basin Plan and local water sharing plans prepared under the NSW *Water Management Act*, and (iii) the benefits to Indigenous people from re-allocation of water to the environment. Human ethics clearance

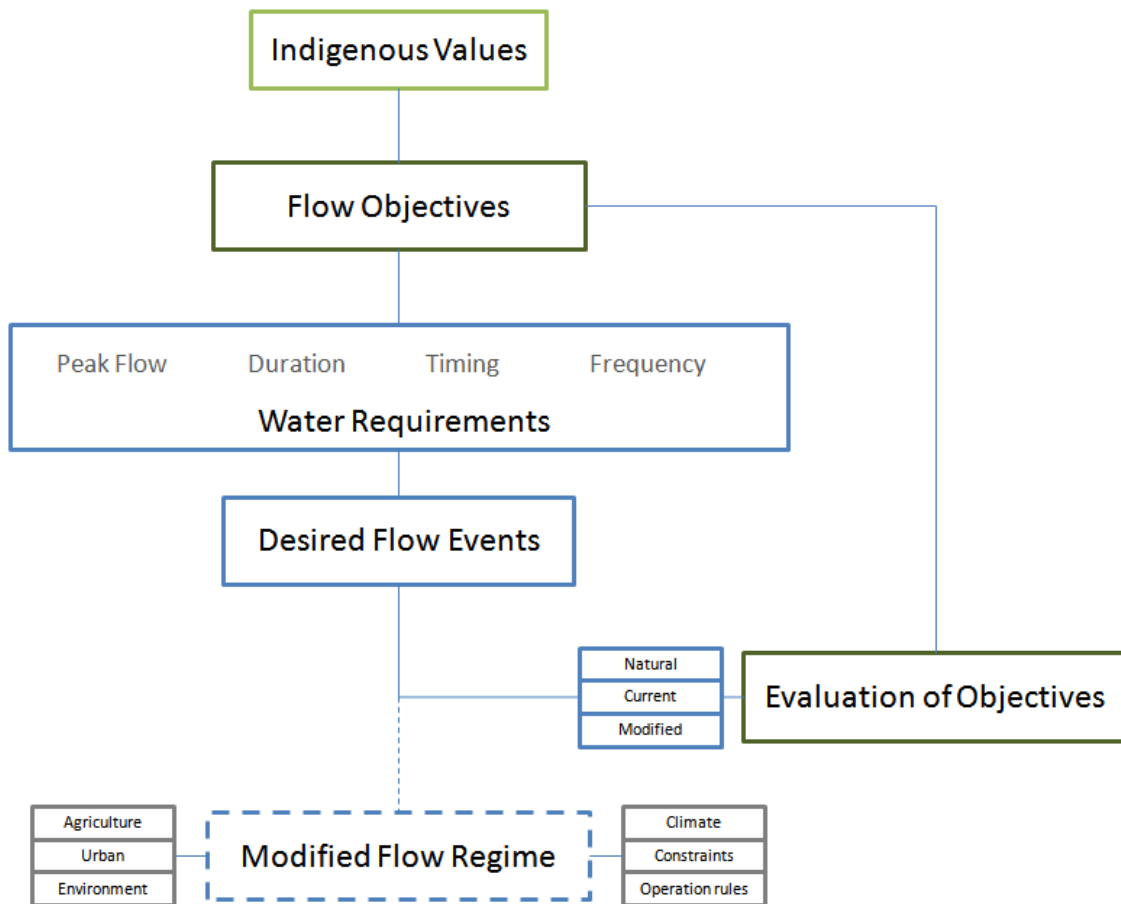
was received for both studies and the Ngemba component was conducted under a research agreement.

The framework for the analysis applied to both case studies commenced with elicitation of Indigenous values (see Figure 2). We drew on the approach proposed by Finn and Jackson (2011) in their adaptation of the ELOHA framework by explicitly distilling the social needs and values that define the ecological objectives applying to each river or management area. Once obtained, these Indigenous values and ecological objectives were used to define a set of flow requirements. The flow requirements to achieve ecological objectives were established using methods typically applied in biophysical environmental flow assessment contexts (Poff et al., 1997; Tharme, 2003), as outlined in Poff et al. (2010). Flow characteristics that are used to describe desired environmental flows are the flow magnitude (e.g. peak flows) and the seasonal timing, duration and frequency of each desired event. The frequencies at which these events of various magnitudes occur were evaluated against the frequencies achieved under a set of flow scenarios. Differences between desired flow frequencies and scenario flow frequencies are used to evaluate whether flow objectives related to Indigenous values are satisfied.

4.2.1 Indigenous values and ecological objectives

In the case of the Wamba Wamba study (Werai forest) information was collected from a one day workshop conducted with 12 Aboriginal people from the community. Comprehensive notes were taken and a transcript was sent to participants to check facts and interpretations (see CSIRO, 2012).

Figure 2. Framework of analysis applied to case studies



An atypically comprehensive data source was available in which resource use patterns were recorded on a series of Land and Occupancy Maps of the area. These maps show the places visited by Wamba Wamba people to hunt, fish and collect food and medicinal and ceremonial

plants. In sum they contain over 10,000 records of resource use and cultural activity (Neil Ward, pers comm). There are 349 registered Aboriginal cultural sites in the forest (burial sites, ovens, mounds, scarred trees, story sites, stone artefacts). The locations recorded within the forest environment provide evidence of long term occupation of the forest environment (at least 10,000 years) and substantial human populations (Yarkuwa Indigenous Knowledge Centre Aboriginal Corporation, 2009) however these cultural sites were not included in the analysis to follow.

With respect to the Ngemba case study (Barwon-Darling River), information was collected from semi-structured interviews, focus groups and photovoice elicitation (see Maclean 2012a) obtained from two field visits. Three interviews and four focus groups (n=17) were conducted with interested Ngemba participants to elicit information on the use and values of the Barwon River, the significance of the area and Ngemba people's understanding of the hydro-ecological system and water management issues. A focus group of six used photovoice (a qualitative visual methodology that employs photography (see Wang and Burris, 1997; Baldwin and Ross, 2012) as the means to engage with a younger cohort of research participants and members of the Ngemba Billabong Restoration and Landcare Group who have an active interest in working at the Ngemba Old Mission Billabong IPA.

4.2.2 Defining and evaluating water requirements

Water requirements were defined as a set of hydrologic requirements that quantify an acceptable flow regime (or particular flow demands) (Lankford, 2003). For the Wamba Wamba case study,

water requirements defined for elicited Indigenous values related to flooding and the wetting of habitats of importance to selected species of flora and fauna. The habitat for species were consistent with the targets defined in the Murray-Darling Basin Plan (MDBA, 2012a) for the Edward-Wakool River, being based on commence-to-fill data defined in an earlier study (Green and Alexander, 2006), who used field site studies. For the Ngemba case study, the objectives were specific to the Mission Billabong, for which water requirements had not previously been defined. The analysis relied on field site surveys to derive commence-to-fill data, reported in (Maclean et al., 2012) as described above, to derive the water requirements of the Billabong.

The flow analyses for both sites sought to describe hydrological differences, comparing three scenarios: 'Without Development' (a 'natural' flow regime surrogate), 'Baseline' (existing river operating rules and infrastructure) and 'Basin Plan' (this includes a sustainable diversion limit that returns 2800GL/year of water to the environments of the Basin). Flow simulation data derived during the development of the Basin Plan (MDBA, 2012) was used for the comparison of flow scenarios. The period of the simulation was 114 years (1895-2009), a period that incorporates climate variability. Each scenario was defined by a set of rules which was used to represent water management scenario alternatives.

To explore the hydrological differences between each flow management scenario, average annual flows and annual recurrence intervals (ARIs) of flow were calculated. An ARI represents a flow event of particular magnitude/size, such that an ARI of 1-in-1 year represents a flow event expected to occur on an annual basis, with flows of increasing size expected to occur with reduced frequencies. The software used to calculate these flows was the River Analysis Package

(downloaded from <http://www.toolkit.net.au/>; Stewardson and Marsh, 2004). The outcome of this is a basic assessment of hydrological change at the site.

To understand the frequency at which indigenous flow requirements were met for each of the flow scenarios, eFlow Predictor v 2.04 (downloaded from <http://www.toolkit.net.au/>; Little et al., 2011) was used. This software was used to quantify the additional volumes of water required to meet specific flow rules, relative to the baseline model. In heavily allocated river systems this provides an estimate of the volume of water that would need to be diverted from consumptive use in order to meet those additional (in this case Indigenous) objectives.

5.0 Results

5.1 Wamba Wamba Case Study (Werai Forest, Edward-Wakool River)

5.1.1 The significance of the Werai Forest to the Wamba Wamba

The Werai Forest is described as a special place for Wamba Wamba people: it is a place 'seen by most of the local community as home' (Yarkuwa Indigenous Knowledge Centre Aboriginal Corporation, 2009; Weir et al., 2013). A strong sense of attachment to the area was evident from the workshop discussion. One participant stated that 'Werai is one of those places that people feel more comfortable going to', another said 'your ancestors come from there. It's the strong cultural connections'. Community members derive a range of social, economic and cultural benefits from their use of and interaction with the Werai Forest. The area supports many cultural activities (Weir et al., 2013) and was described as a 'supermarket' by workshop participants; providing many food items such as kangaroos, ducks, eggs, emus, and fish. The

Wamba Wamba revealed the importance of a number of landscape features, especially the lowland vegetation systems (including cumbingi, *Typha* sp.), the red gum and black box systems, species of waterbirds (swans, brolgas, herons) and ecological processes such as fish breeding, particularly during flood periods.

5.1.2 Hydrologic assessment of anticipated differences from Basin Plan

To assess hydrologic differences between flow scenarios, we used modeled time series to evaluate change in annual average flows, change in flow intervals, and change in flooding of the forest. An analysis of modeled average annual flows at Deniliquin on the Edward River shows a reduction in water available within the river system from the Without Development 2366 GL/y, to the existing Baseline of 1688 GL/y and modeled 1833 GL/y under the Basin Plan scenario. Using ARIs to describe important flow events, the flows that would have occurred greater than 1-in-2, 1-in-5 and 1-in-10 years under the Without Development scenario are approximately halved under the Baseline and Basin Plan scenarios, however, annual events (1-in-1) are relatively similar (Table 1).

The flooding behaviour of the Werai Forest area is complex and poorly studied, which limits the ecological knowledge available for establishing water requirements. Observational data shows that substantial flows are needed to inundate the Werai Forest, with flows in the Murray River needing to exceed 10,400 ML/day at Yarrawonga Weir (MDBA, 2010). Flows of 2,150 ML/day at Stevens Weir on the Edward River provide a reasonable flow to the forest, inundating approximately 150 ha of predominantly wetland areas (Green, 2001). Flows of 2,500 ML/day at

Stevens Weir were estimated to flood 270 ha of wetland areas (Green, 2001). Under the Without Development scenario, 156 events of this size occurred over the modelled period compared with the Baseline of 385 events. The mean duration of events is much longer under Without Development (137 days) than that of the Baseline (31 days). These differences are consistent with what would be expected for a regulated river, where low flows occur more frequently, and often unseasonally, and for shorter periods than would have occurred naturally.

Table 1. Flow event size (in ML/day) for annual recurrence intervals (ARIs) under the 'Without development', 'Baseline' and 'Basin Plan' (BP 2800) scenarios at Deniliquin. BP 2800 includes a sustainable diversion limit that returns 2800GL/year of water to the environments of the Basin.

Average recurrence intervals	Without development	Baseline	BP-2800
	ML/day		
1-in-1 year	3,080	2,171	3,517
1-in-2 years	25,422	11,076	12,304
1-in-5 years	55,901	28,827	26,718
1-in-10 years	80,959	48,513	41,044

5.1.3 Ecological assessment of water requirements

Green and Alexander (2006) defined critical flow requirements for maintaining the ecological community of the Werai Forest. These requirements were used by the MDBA to derive water

requirements for the Edward–Wakool River system (MDBA, 2012b), which incorporates the Werai Forest. These flow requirements are defined as a peak flow, a duration and timing (Table 2). Associated with these requirements are a low and high frequency, and these bound the proportion of years that flow events are required to achieve an ecological target.

Table 2. Environmental Watering Requirements expressed as ecological objectives and flow requirements in the Edward-Wakool River system, with Deniliquin being the river measurement gauge. Flow requirements are as defined in MDBA (2012a) and targets are as defined in Green and Alexander (2006).

Ecological objectives	Flow Requirements			Frequency	
	Flow Required ML/d	Duration (days)	Timing	Low uncertainty	High uncertainty
Fish habitat	1,500	180	June to March	100	99
Reed beds and low-lying red gum communities	5,000	60	June to Dec.	70	60
	5,000	120		40	35
Flooding of significant areas of red gums and ephemeral streams	18,000	28		30	25
Inundate ephemeral streams and areas of black box	30,000	21		20	17

An analysis of flow scenarios shows that the majority of water requirements are met at the specified frequency for the Without Development scenario, but none are met under the Baseline

(Table 3). Under the Basin Plan scenario, the 5000 ML/day flow requirements are achieved. It should be noted that the Basin Plan represents only one option for managing flows. Nonetheless, to meet the flow requirements in Table 2, on average an annual flow of 1,864 GL/year is required at the Deniliquin gauge. Whilst the Without Development scenario meets this annual flow, the Basin Plan scenario represents a shortfall of 122 GL/year. This outcome suggests that the additional volumes of water in the river do not meet water requirements over the scenario evaluation period, regardless of how the river system is operated.

Table 3. Assessment of Environmental Watering Requirements (from Table 2) against the Without development, Baseline and Basin Plan 2800 scenarios for the Edward-Wakool River system. Bolded values indicate where requirements defined in Table 2 are achieved.

Ecological objectives	Proportion of years with an event		
	Without development	Baseline	2800 Scenario
Fish habitat	75	97	95
Reed beds and low-lying red gum communities	83	39	63
	52	22	36
Flooding of significant areas of red gums and ephemeral streams	40	15	16
Inundate ephemeral streams and areas of black box	28	12	11

Given flow delivery constraints in the Murray River and the Edward-Wakool River, flow requirements above 18,000 ML/day are limited by constraints posed by storage operations (i.e. maximum release volumes) and flood risk to floodplain development and infrastructure (MDBA, 2012c). Flows of 18,000 ML/day and above require unregulated flows that result in flooding: such flood events occurred in 2010 and 2011.

5.1.4 Benefits of increased environmental water

Additional water is predicted to meet habitat requirements for water bird breeding, which, if realized, would represent a substantial gain for the Werai forest and the Wamba Wamba people. However, whilst the Basin Plan scenario represents an improvement relative to the Baseline scenario, additional water allocated under the plan scenario still falls short of meeting the Werai Forest environmental water requirements in their entirety (Table 2), defined in MDBA (2012a). For example, operating constraints prevent flooding of black box forest. Black box is regarded as a characteristic tree of the Werai Forest, and these forests remain vulnerable to further change. Further Opportunities will therefore need to be sought to address unmet watering requirements.

5.2. Ngemba case study (Barwon-Darling River, Brewarrina)

5.2.1 The significance of the Billabong and Barwon-Darling River to the Ngemba

The Barwon-Darling River, the Billabong and the fish traps (referred to as '*Baiame's Ngunnhu*' by the Ngemba) are of spiritual significance, representing important sources of cultural inspiration and providing opportunities for recreational and subsistence pursuits such as fishing and collecting bush tucker. Two elders described why these places are special to them: 'all legends, stories are along the river, for example where the billabong meets the river: it's where

the spirits are'. The fish traps, as well as various other sites along the River (scarred trees, mussel middens, tool-making sites, burial grounds, ochre pits and hearths) provide evidence of past occupancy. Many of these cultural heritage places are protected under the NSW *National Parks and Wildlife Act 1974* and provide a way for generations of Ngemba people to connect to the 'old people' and celebrate past cultural practice.

Environmental protection is a priority for the Ngemba people and the recent declaration of part of the Billabong site as an IPA is expected to enable a more holistic management approach to restoration. The Ngemba aspire to develop partnerships to manage the river and billabong system in culturally appropriate and ecologically responsible ways that also generate sustainable livelihood opportunities for younger generations.

Ngemba participants reported the main causes of decreasing water quality and habitat loss are changed flow regimes due to water extraction and introduced species (European carp, cattle). As decreasing water quality is a key management concern, some participants are keen to develop an Aboriginal led water monitoring program. A native plant nursery to supply seedlings for riparian revegetation programs and a small native fish nursery are also proposed. Participants listed important species they would like to see return to the river and billabong system: aquatic plants (water weed, water lilies, marpu tree, native bird of paradise, marshmallow grass, pigface), animals (emus, kangaroos, water rats), insects (dragonflies, witchetty grubs, grasshoppers, centipedes), fish species (yellow belly, black bream, Murray cod, catfish, bony bream), crustaceans (mussels, blue crayfish, shrimp) and other aquatic species such as brown frogs and turtles.

5.2.2 Hydrologic assessment of anticipated differences from Basin Plan

The Barwon-Darling River is subject to river regulation through diversions, weirs and off-stream storages. An analysis of average annual flows at Brewarrina shows that the total availability of water within the river system has been reduced as a consequence of regulation, with Without Development flows of 6254 GL/y, Baseline flows of 3782 GL/y and Basin Plan flows modeled at 4156 GL/y. Differences in the ARIs for each of the flow scenarios at Brewarrina were used to represent changes in flow across the flow hydrograph. Flows that would have occurred greater than 1-in-2 years under the Without Development scenario are approximately halved under the Baseline and Basin Plan scenarios (Table 4). This scale of difference is evident across the flow recurrence intervals.

Table 4 Flow event size for average recurrence intervals under the Without-development, Baseline and Basin Plan scenarios at Brewarrina

Average recurrence intervals	Without development	Baseline	BP_2800
	ML/day		
1-in-1 year	13,639.3	6,440.1	7,106.5
1-in-2 years	34,555.05	18,410.9	19,021.5
1-in-5 years	60,966.6	37,060.5	37,684.3
1-in-10 years	8,9231.6	64,102.6	65,346.0

Whilst knowledge of the environmental water requirements at the Billabong is sparse, commence-to-fill volumes (44,000 ML/day), the flow that is required to reconnect this billabong to the Barwon-Darling River (66,000 ML/day), and the total volume that is required to fill it (650 ML), were defined as part of Maclean et al. (2012).

The volumes of water that are required to return or mimic a 'natural' flooding regime are assessed here, where an additional annual average volume of water is quantified. This volume is defined according to two objectives: (1) to re-connect the Billabong to the Barwon-Darling River (water flowing into the Billabong and back out to the river); and (2) to reach the commence-to-fill flow to the Billabong, but not to reconnect the Billabong back to the river. To meet Objective 1 at the frequency that mimics that under the Without Development scenario, an additional 13.5 GL/year, on average, is required. Under the Basin Plan scenario, this shortfall is reduced to 12.9

GL/year. To meet Objective 2 an additional 8.9 GL/year is required for the Baseline scenario, and an additional 8.5 GL/y is required for the Basin Plan scenario.

Comparisons of modelled scenarios show that the frequency of filling of the Billabong and frequency of connection of the Billabong to the Barwon-Darling River have declined as a consequence of river regulation and existing water management. Under the Without Development flow scenario, the Billabong would reach a commence-to-fill flow approximately once every three to four years. Under the Baseline scenario, this would occur approximately once every six to seven years. In terms of connecting to the Barwon River, under the Without Development series, this would occur once in every seven years, but this is reduced to one in ten years under the Baseline scenario.

The reduced occurrence of flooding of the Billabong is likely to have led to a decline in the suitability of habitat for aquatic species, including fish and aquatic plants. Fish habitat would be important for feeding and for spawning of fish, whilst aquatic plants require flooding to germinate and set seed upon drying and to complete their lifecycle requirements. In reconnecting the Billabong to the Barwon-Darling River, fish could move back into the river and carbon and nutrients from the Billabong could be flushed out and enrich the river. If these nutrients are further concentrated in a billabong as a result of reduced flooding, a decline in water quality could occur.

5.2.3 Benefits of increased environmental water

The water entitlement previously available to the Aboriginal corporation holding title to a portion of the Billabong is 753 ML/year. Although this amount is enough to fill the Billabong, it is not enough to generate an event that can reach the lagoon commence-to-fill volume of 44,000 ML/day. To suggest how best to use the water entitlement (assuming 100% allocation) we explore two options: (a) to extend overbank flooding events when they do occur or (b) to use pumps to fill the Billabong at the desired frequency. To assess the benefits of filling the billabong, we focussed on the benefits to fish communities, using an existing wetland fish model documented in Gawne et al. (2012), which consists of a set of Bayesian networks that synthesise expected fish population responses to alternative wetland flooding regimes and modes of connection to the river. The models were used to determine the optimal timing and method of billabong filling to achieve outcomes for native fish species with differing flow requirements: golden perch (*Macquaria ambigua*), Australian smelt (*Retropinna semoni*) and carp gudgeons (*Hypseleotris klunzingeri*). Outcomes for an invasive species, the European carp (*Cyprinus carpio*) were also considered in the analysis. The results are only preliminary and based on a set of assumptions regarding the characteristics of the Billabong.

Using the wetland fish models, we found that to maximize outcomes for golden perch, the ideal times for inundation are September to February. Periods outside these bounds are likely to preference carp. It is worth noting that if a flow event was to occur outside this window, allowing the wetland to dry out post-wetting would result in other environmental gains (i.e. carbon cycling; water use for vegetation), whilst minimizing opportunities for carp to re-enter the river. For golden perch, water from a large permanent river channel and inundations through natural filling processes are preferred. Pumping is unlikely to result in any benefits for large

native fish (Gawne et al., 2012; Bond et al., 2014). For smaller bodied fish, such as smelt and gudgeons, the method of filling and the source of water are less important.

6.0 Discussion

The Australian government is committed to the restoring aspects of the river hydrology in the MDB primarily for the benefit of river and floodplain environments. At the same time, there is an expectation that state-led water resource plans consistent with the overarching Basin Plan will strive to incorporate Indigenous water management objectives. Achieving this will require both an understanding of Indigenous water needs and actual improvement in Indigenous access to water (MDBA, 2012a).

Two case studies, from different regions of the Basin, address the critical research need arising from the policy objective to increase Indigenous water access (NWC 2011). These case studies illustrate a methodology to integrate social and environmental objectives into environmental flow assessments. Participants shared their water values, the water requirements necessary to support these values were quantified, and the authors assessed whether these water requirements would be met under three alternative water management scenarios, including one that entails a substantial reallocation of water to the environment. Analyses include the full range of impacts that changes in water availability would have upon traditional lands, river features (e.g. billabongs) and aquatic resources, and some of the benefits that might be derived from improvements in environmental condition. Such a methodology can support environmental assessment processes by accounting for the social, cultural and environmental benefits that

Indigenous groups derive from water. It can also provide a way to include Indigenous knowledge and valuations in integrated environmental flow assessments.

Not surprisingly, the results show that Indigenous values are best satisfied under pre-development flow regimes. As one of the Wamba Wamba people involved in this study stated: 'My people's spiritual and religious connection to country are directly linked to, and cannot be separated from, the environment' (J. Crew cited in Weir et al., 2013 p.5). An Ngemba participant similarly linked culturally significant places to healthy environmental conditions: 'water places are natural bird habitats...when the billabong is healthy we see lots of different bird species – ibis, brolgas, ducks, galahs, budgies'.

Although the Basin Plan represents an improvement on the current arrangements (the Baseline condition), it still falls short of meeting flow requirements desired by the Wamba Wamba and the Ngemba people to keep their respective lands, rivers and wetlands 'healthy'. Wamba Wamba participants suggested that a different watering regime may be needed for the Werai forest to account for recent changes to vegetation patterns. This group seeks a more consistent and 'balanced' delivery of water under a flow regime that restores a balance between the distribution of red gum and black box vegetation communities and provides suitable habitats for fish and waterbirds. In the northern basin, the Ngemba are seeking flows to maintain the function of a key billabong. Ngemba advocate that water be allocated to sustain the 'life force' flow of the river, to connect the billabong to the river at times of high flow and to enable local sustainable development enterprises. However, similar to the Wamba Wamba case study, the volumes of water allocated to restore environmental values under the Basin Plan are insufficient to meet the

Ngemba objectives of either reconnecting the Billabong or the less demanding commence-to-fill flow requirement.

Regulation of the rivers of the Murray-Darling Basin has generated deleterious impacts on affected Indigenous communities whose values are closely related to the Without Development flow regime. According to Weir et al. (2012 p. 10) for example, regulation of variable flooding regimes has been 'central to the declining health of the Werai forests and the culture that lies within them'. Yet returning to Without Development flow regimes is unlikely given the economic concerns of agricultural communities that have developed enterprises and homesteads dependent on irrigation enterprises and a regulated flow regime with reduced flooding risk. Solutions that involve alternative delivery scenarios, where river operation is 'optimised' spatially or temporally, to meet specific Indigenous environmental water requirements while simultaneously reducing the need for additional water recovery, are likely to be more acceptable to the majority population (Jackson et al., 2011). All impacts will need to be carefully considered as, for example, pumping water into individual wetlands or billabongs is not likely to result in any benefits for large native fish (see review in Bond et al., 2014).

In these studies we found that Indigenous communities are willing to engage in flow assessment research and, moreover, that communities aspire to a stronger role in environmental water management (see Weir et al., 2013). The groups concerned articulated a broader understanding of the term 'water requirement' than one that denotes a volumetric allocation directed to their uses. Both groups seek to identify flow regimes that will meet their needs and, in addition, to

participate directly in environmental and wider water management. For instance, the Werai Forest will soon be governed under a joint management regime between traditional owners and the NSW Parks and Wildlife Agency (Weir et al., 2013). Similarly, the Ngemba, who have a water license and are landowners of a protected area, seek the knowledge and capacity to engage in wider water management activities and to generate sustainable livelihoods from water-based enterprises such as fish farming and heritage tourism focused on the fish traps at Brewarrina (Bark at al., in review).

7.0 Conclusion

Use of MDB water resources is highly contested and water managers face the problems and challenges typical of many large river basins globally: over-extraction of water for irrigation, declining health of flow-dependent ecosystems and climate change impacts that are expected to reduce inflows (Arthington, 2012). Water managers also confront the need to account for the multiple and diverse social and cultural values people ascribe to aquatic ecosystems and to redress the neglect of Indigenous priorities in water allocation frameworks that remains a significant problem in Australian and internationally (Bark et al., 2012).

Using the framework developed in Finn and Jackson (2011), we defined a consistent process that examines the effect of flow regime restoration on Indigenous people and their value systems in two case studies under three flow scenarios representing the past, present and future of water management. Although the values identified and the knowledge base used to define water requirements are different in each case, this paper demonstrates how Indigenous knowledge,

values and priorities can influence the setting of water requirements through valuation, assessment and planning processes. Results suggest that the landmark Murray Darling Basin Plan represents an improvement from the current water allocation arrangements, but that it will fall short of meeting Indigenous flow requirements. There is therefore a need to explore alternative policy mechanisms such as the purchase of entitlements for Indigenous use (Jackson and Langton, 2012).

The paper demonstrates the potential for EFA methods such as ELOHA (Poff et al., 2010; Finn and Jackson, 2011) to address direct Indigenous use of water. Nevertheless, further discussion is required amongst Indigenous communities, water planners and eco-hydrologist specialists to extend these methods to meet a wider array of less tangible Indigenous needs, for example, sacred or heritage sites. In today's regulated river systems it will be challenging to meet all Indigenous values developed over many thousands of years under naturally variable water regimes. An option that has been posed by others is the use of the natural flow regime as the preferred flow target – a widely espoused paradigm of environmental flow science (Poff et al., 1997; Arthington, 2012). Another option that may be suited to a situation where culturally sensitive knowledge underpins a value is to adopt flow thresholds, and have the value unstated. The adaptation and trial of these and other methods for determining water requirements will require Indigenous input to ensure they deliver practical, credible and fair outcomes from water allocation processes. Furthermore the planning and implementation process needs to be monitored and progress evaluated to ensure Indigenous values and objectives are met.

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