Dialogue
ON WATER, FOOD AND ENVIRONMENT

INTERNATIONAL WATER CONFERENCE
Hanoi, Vietnam,
October 14-16, 2002

Environmental Flows: Lessons from an Australian Experience

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ENVIRONMENTAL FLOWS: LESSONS FROM AN AUSTRALIAN EXPERIENCE

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1 INTRODUCTION

"Environmental Flows" have been variously defined as anything from the explicit allocation of water for specific conservation purposes to a suite of management arrangements aimed at ensuring a holistic flow regime capable of sustaining a complex set of aquatic habitats and ecosystem processes. In the first case the allocation is typically an annual volume whose size is unrelated to the residual flows in the system, but is generally released to create or enhance selected high flow events. Establishment of an environmental flow regime, on the other hand, seeks to maintain or restore a proportion of the flows across the total regime although it may, depending on the specific circumstances, place particular emphasis on the restoring the frequency of median to high flow events, flow variability and/or reducing the frequency and intensity of dry periods.

Simple environmental allocations dominated the claims for environmental water in Australia during the 1980's and early 1990's. Typically these were sought as a basis for a wildlife release to a high profile wetland or to create the reproductive conditions necessary for an endangered or highly valued animal species. Two significant examples in Australia were the 125,000 Megalitre/year Wildlife Allocation for the Macquarie Marshes in central New South Wales initiated in 1986, and the 100,000 Megalitre/year allocation for the Barmah/Millewa Forest in the Murray Valley initiated in 1991. Management of these environmental allocations have, however, often been controversial, raising significant questions about the nature and purpose of environmental flows and how decisions should be made about their use.

Since the mid 1990's environmental flow provisions have been designed and implemented in most of the major rivers regulated (or controlled) by dams in New South Wales (an eastern state of Australia). These provisions largely moved away from the notion of an annual allocation of water managed by a conservation agency or trust, to a more complex set of environmental flow rules involving recent concepts in a package of:

1. water extraction rules to preserve remaining elements of the natural flow regime through mechanisms such as:
   - annual or long term water extraction limits,
   - restrictions on extraction from natural high flow events,

and

2. specific water allocation and release rules to restore elements of the natural flow regime through mechanisms such as:
   - water released from dams, the releases triggered by inflow events (dam translucency rules),

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- environmental contingency allowances (a nominated volume of water held in storage to be used to “treat” environmental problems as they arise, for example algal blooms or an overly rapid recession of wetland inundation threatening the success of a bird breeding event).

At the same time, environmental flows have been a primary consideration in a major review of water management across the extensive but generally less developed network of rivers in New South Wales whose flow is not controlled by dams. In these river systems, where water users are dependent on pumping from the natural river flows, environmental flow protection is now being achieved through:

- the application of annual volumetric limits on licences,
- setting minimum flow levels below which non-essential pumping is prohibited and,
- where necessary, daily extraction limits set as a proportion of the daily flow.

These recent environmental flow initiatives have required a more comprehensive assessment of stream hydrology and ecosystem response and resilience. It has also required development of technical tools (computer models etc) and greater understanding of the dynamics of extractive water demands and irrigation practices so that the long-term impacts of proposed changes can be accurately forecast.

Environmental flow initiatives have been a major component of the management changes aimed at achieving more “sustainable” use of the water resource. The other components have sought to foster improved economic returns from the use of available water supply. These have included :

- new water accounting methods that provide farmers with more flexibility regarding when they use their available supply,
- expansion of water trading opportunities,
- improved water rights specifications.

These factors have both influenced the design of environmental flow measures and helped to reduce their economic impact.

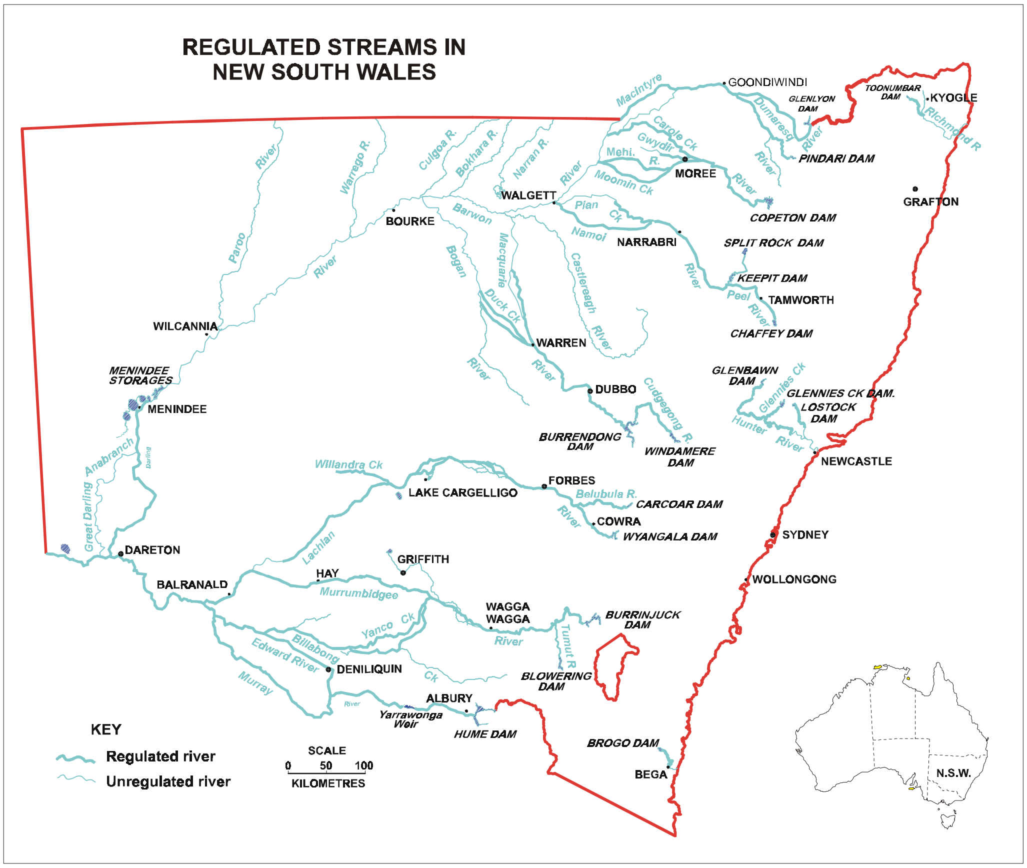
This paper will draw on the New South Wales experience to try to shed some light on the following issues;

- the choice of flow statistics in analysing the environmental impact of water resource development,
- the difficulties inherent in redressing the impacts of water resource development once they have occurred
- the importance of setting annual extraction limits as a prerequisite of more specific environmental flow provisions
- the value of objective, preset environmental flow rules
- the consideration of economic impacts in the design of environmental flow provisions

2 THE NEW SOUTH WALES SITUATION

New South Wales (NSW) lies on the eastern seaboard of Australia (figure 1). About 80% of the state is within the Murray-Darling Basin, which drains westward and enters the sea near Adelaide in South Australia. The major tributaries of the Murray Darling River have been substantially regulated through large storages and a range of re-regulating and diversion structures. More than 90% of the water use from these streams is for irrigation. The headwaters of the Murray-Darling and the eastern coastal areas of the State are dissected by numerous unregulated rivers and streams many of which support significant irrigation, urban and industrial activities. There is also considerable use of groundwater in some areas.

Figure 1: NSW Rivers whose flow is controlled (regulated) by dam operation



Since the 1950s, and as a result of government policy to encourage irrigation development, there has been continued growth in the amount of water extracted from these rivers and connected groundwater systems (MDBMC 1995). Among other things, the amount of water extracted has significantly reduced river flows, with the median annual flow at the end of several western regulated rivers now only 30 percent to 50 percent of that which would have occurred prior to development. This reduction has most notably affected the frequency of small to medium sized freshes, with many of these events being completely eliminated. Such changes to the flow regime have had a significant impact on river health. There has been a contraction in wetland communities, native fish have declined to an estimated 10% of pre-European levels (Gehrke et al 1995), algal blooms have increased in frequency and intensity, and salt water has been able to move further upstream from coastal estuaries with consequent impacts on freshwater species. Groundwater levels have also declined in many aquifers as a result of extraction (DLWC 1998), with consequent impacts to the baseflow contributions to rivers and to the health of dependent ecosystems. At the same time social and economic dependency on these water resources has significantly increased making it increasingly difficult to redress the environmental damage.

Since the early 1990's, the issue of environmental flows has been high on the conservation and political agendas and has become the centre of substantial community debate. Despite the continuing controversy over the justification for and impact of environmental flows, the growing evidence of environmental damage coupled with the economic pressures to better define and protect water rights, particularly from downstream water users, has driven a range of environmental flow initiatives in recent years.

The rivers of New South Wales are characterised by highly variable flows and this variability is a major determinant of river ecology. While flow variability may not be so pronounced in South East Asia and other parts of the world, the principles and many of the approaches and lessons learnt in New South Wales will be relevant to other systems.

3 WHEN ARE ENVIRONMENTAL FLOWS REQUIRED?

The change in average annual runoff is often quoted to indicate the current level of extraction from rivers or to argue against the need to address environmental flows. However, annual statistics tend to understate the impact of resource development and analysis of rivers in New South Wales has shown that annual statistics are a very poor index of impact. This is because a large percentage of the total river flows come as infrequent very large floods which easily fill and spill the headwaters dams and pass through the river systems relatively unaffected. Their inclusion masks the effect of river regulation and water extractions on the flows that occur most of the time. Furthermore the ecology does not respond to cumulative or average volumes of flow but rather responds to the sequence and range of instantaneous flows. The characteristics and timing of these flows can be substantially modified by water resource development even in locations where the average flow has been little altered, such as immediately below headwaters dams.

Daily flow statistics therefore provide a more meaningful indication of the likely ecological impact of flow change. Table 1 demonstrates how a different perspective can be put on the hydrological impact of water resource development depending on the statistic used. Current analysis of environmental flows in New South Wales has focused on daily rather than annual data. In less variable rivers weekly or monthly flow data might be appropriate.

Table 1: Flow data for western NSW rivers

	Reduction in end of system flows as % of natural (1993/94 development and management rules)				
	Avrg Annual Flow	Median Annual Flow	Reduction in frequency of flows		
			High Flows	Moderate Flows	Median Flow
Murrumbidgee River	48%	62%	50%	64%	81%
Lachlan River	22%	46%	29%	58%	39%
Macquarie River	31%	59%	32%	52%	66%
Namoi River	28%	53%	42%	44%	49%

Average annual statistics can also mask the seasonal affects of development and it is useful to analyse the daily flow impacts for each month or season both to provide a better indication of the character of the seasonal flow regime, the seasonal ecological characteristics, how resource development may impact across the seasons, and the effect that different environmental flow rules can have on these seasonal flows.

Hydrologic analysis of historic and/or modelled daily stream flow data can quickly indicate the scale of flow reduction which has or could occur, and can signal the need for environmental flows. There is a growing body of evidence which demonstrates that as river flows are increasingly modified, not only is their ecological character changed but the basic health of the river becomes compromised (Hillman et al 2000, Bren 1988, Gehrke et al 1995, Kingsford 1995, 2000, Walker 1985). Generally the more developed the river, the greater the reductions in flow and alteration of the flow regime, the less natural its ecology becomes and the less healthy it is. This is because the changes that development imposes on a river and its environment affect the basic ecological functions and values that a natural river provides such as the provision of clean water, energy production, nutrient cycling, and sustaining river and coastal fisheries and water bird habitats and populations.

A useful concept which can underpin environmental flow considerations is that of a "healthy working river" (CRC for Freshwater Ecology in Watershed, February 2002; Hillman et al., 2000). This concept accepts that most rivers must continue to be worked to provide essential economic and social benefits. But it cautions that the impacts must be limited and managed to appropriate levels in order to indefinitely sustain an adequate level of health and ecological functioning.

Many rivers and aquifers are now being used at a level that is likely to result in ongoing deterioration in environmental health. Proposals to substantially develop others are still being considered. The resultant decline in health is likely to be unacceptable to this generation and disastrous to future generations. It is therefore critically important to moderate potential impacts and where necessary actively work to reinstate critical flows and restore key ecological processes and biodiversity. In particularly it is essential that extraction limits and more specific environmental flow provisions are established in relatively undeveloped rivers before the damage is done and before unsustainable financial investments have been made and/or unrealistic social expectations developed. As once development has occurred it is very difficult to change the "water rights" and redress the environmental damage.

4 WHAT FLOWS DOES THE ENVIRONMENT REALLY NEED?

Research into environmental flows has historically focused on the flow requirements of a very limited set of highly valued or "icon" species typically fish or waterbirds. There were a number of reasons for this:

- they were typically very visible or highly valued recreational or economic species which easily garnered public support
- much of the evidence of environmental decline was based on these species, and therefore the simple response was to improve the flows specifically for them rather than to see them as an indicator of a much broader problem,
- more data was available on these species,
- It was argued that if the environmental flows were designed for these species then it was likely that other elements of the ecosystem would also benefit.

More recently, however, the scientific community has argued that healthy functioning ecosystems are fundamental to the continuing survival of these and other plant and animal species as well as to the human communities and economies that depend upon them (Hillman et al 2000, Poff et al 1997, Robertson et al 1999, 2001). The movement of water, the transported sediments and nutrients, and wetting and drying cycles profoundly affect the ecology and productivity of aquatic or semi aquatic systems. Water movement affects how energy (mainly in the form of organic carbon) flows through the system, the nature of interactions between organisms in the food web, and the ecology and life strategies of those organisms. The habitat life cycle/reproduction requirements of an individual species does not necessarily reflect the role that different elements of the flow regime play in maintaining these critical ecological processes.

In order to protect or improve aquatic biodiversity, it is therefore important to ensure that, as far as possible, environmental flows address the full spectrum of habitats and the differing requirements of all species within an ecological community which must coexist in order to ensure the health and survival of the whole.

Flow regimes and the resulting fluctuating water levels, varying hydraulic conditions and intermittent channel and floodplain wetting and drying play a critical role in:

- determining habitat availability and condition,
- connecting aquatic and floodplain ecosystems,
- food production (eg biofilm succession-bacteria and algal communities living on rocks and logs; and plankton blooms- microscopic plants and animals),
- carbon cycling,
- the ratio of production to respiration,

- stony-bed scouring,
- species dominance and competition.

In recent years increased scientific effort has been focused on understanding the basis of ecological primary production and on developing predictive flow-response models. In NSW the "Integrated Monitoring of Environmental Flows" (IMEF) program seeks to gather more information on ecological flow-response relationships such as carbon cycling, biofilm production and stony bed scouring.

There is growing evidence (CSIRO 2001, Gerhke et al 1995) that variable flows across the full regime are critical to water dependent ecosystems and that targeting just one element of the flow, such as an annual high flow event, will not be effective in correcting the general environmental decline resulting from a loss of flow variability. Understanding the role that different elements of the flow regime play in supporting a river's ecology is critical to designing and implementing environmental flows.

Maintaining <u>low flows</u> or baseflows, during dry or drought periods, are important because they will:

- moderate the rate of decline in water quality,
- moderate water temperature increases particularly in unshaded streams,
- maintain refuge areas in pools and wet gravel beds,

The ecological stresses imposed by the very low or zero flows during droughts are a natural and important phenomenon which can play an important role in species succession, predator-prey relations and aerobic/anaerobic decomposition cycles. However, if these conditions occur too frequently or for too long as a result of water resource development, they will reduce the capacity of the ecosystem to recover when conditions improve and may cause the local extinction of more sensitive species. For example, if flows into natural pools are reduced for extended periods, turbulence is reduced and oxygen exchange also declines. Stratification of the pool may eventuate and the oxygen depletion will be accelerated. Dissolved oxygen, which varies naturally with temperature and flow, is critical to many ecological processes and the survival of aquatic species. Low oxygen levels can threaten local populations of sensitive species, reduce biodiversity and favour a few low oxygen tolerant species.

<u>Moderate flows</u>, pulses or freshes typically remain within-channel and wet the top half of the channel cross-section. These within-channel pulses have been found to:

- maintain the channel,
- trigger fish breeding and dispersal events (many native fish do not rely on floodplain inundation for spawning),
- wash carbon from in-channel benches and bars,
- increase turbulence and therefore oxygenation,
- suppress thermal and chemical destratification of pools
- suppress algae growth,
- scour stony beds,
- reset biofilm succession on rocks and snags which increases productivity,
- trigger macroinvertebrate reproduction,

- reduce salt concentrations,
- suppress alien species.

<u>High flows</u> and flood events will break out of the channel in at least some river reaches and:

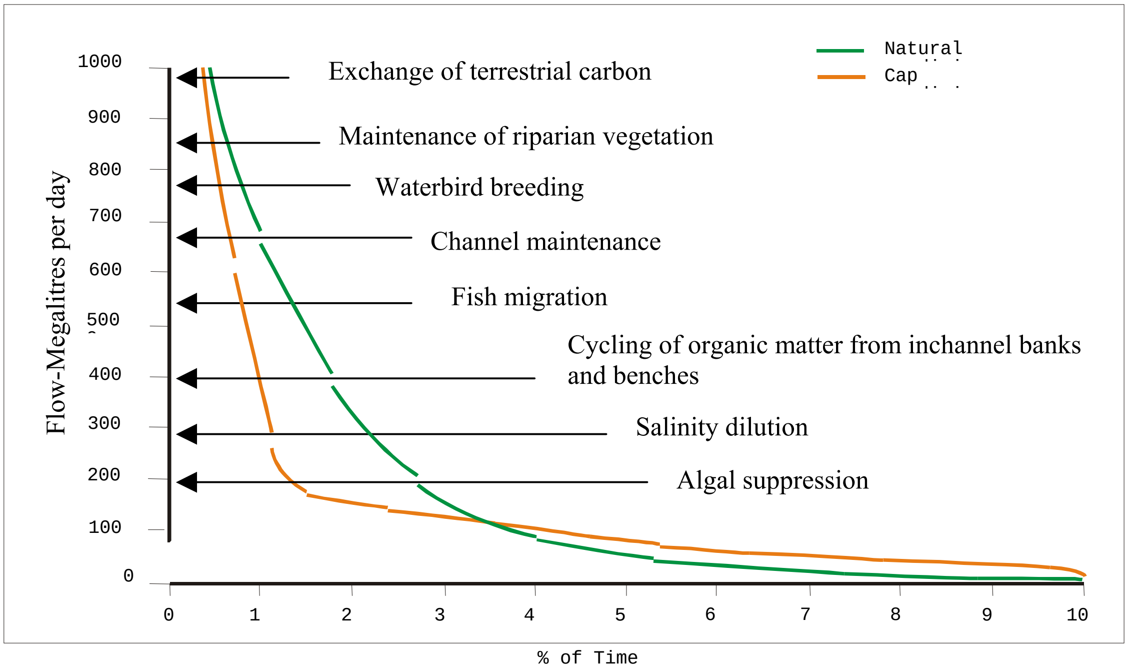
- inundate and rejuvenate wetlands and floodplain woodlands,
- stimulate food production and breeding of a diverse range of aquatic and semi-aquatic species,

- temporarily connect floodplain and instream habitats for the exchange of carbon and invertebrates,
- stimulate native fish breeding and migration and enable distribution of juveniles,
- stimulate waterbird breeding.

Many essential ecological processes depend on the flow conditions alternating between these states. The ecologically desirable duration for each phase will depend on the biophysical characteristics of the region, particularly the natural hydrology of the river to which the ecology was adapted. It is therefore important to analyse the historic streamflow record to appreciate the stochastic characteristics of the natural flow regime and to design the environmental flow provisions accordingly.

A flow duration curve based on the daily flows for a representative (or modelled) period of river flow provides a useful summary of the probabilities of different flows occurring. The flow duration curve plots the number of days on which a daily flow volume is equalled or exceeded. Figure 2 illustrates a typical flow duration curve for a regulated river in New South Wales where flows greater than 7000 Megalitres/day (a high flow event) would naturally occur on approximately 10% of days, flows between 3000 and 7000 Megalitres/day (moderate flows or freshes) naturally occur on 10% of days, and flows less than 1000 Megalitres/day (low flows) would naturally occur on about 40% of days. The graph illustrates the typical impact of river regulation and water extraction on flows. In particular, moderate to high flows are substantially reduced, and low flows increased. Increases in low flow may occur in some parts of the regulated system where irrigation water deliveries, stock and domestic releases supplement naturally low flows. In unregulated rivers, the greatest reduction in flows generally occurs in the low flow range when river pumping will have its greatest impact. Some examples of the types of ecological responses which may be triggered at different flow levels are superimposed on the graph to demonstrate how all levels of flow are likely to be important to maintaining river health. It is likely that the processes which have been compromised most are those where the flows have been subject to greatest impact i.e. 2000 to 6000 Megalitres/day in this example.

Figure 2: Flow duration curves showing the impact of development in a Western NSW River and illustrating the ecological responses expected at different flow levels



One way to maintain flow variability across the full flow regime is to protect or reinstate a proportion of the flows across the entire flow duration curve. The State Water Management Outcomes Plan (2002) for New South Wales sets out long term goals and five year targets to guide water resource management. One of these five year targets seeks to protect or restore flows at approximately 60 percent of their natural frequency. Where flows have been reduced to less than 60% of natural then an improvement of at least 10% is sought within the next 5 years. This target has been based on growing evidence that a river maintaining 60 percent or more of its natural flow has a high probability of sustaining a healthy ecology over the long term. A Stressed Rivers Assessment was undertaken in 1998 for the rivers of New South Wales. It defined "hydrologic stress" as the proportion of the daily low to medium flow which would be extracted by licensed water users during peak irrigation periods. It also considered the level of stress exhibited by a range of other environmental indicators. The analysis suggested that rivers which had a significant proportion of their flows extracted were also likely to exhibit other evidence of environmental stress. The state was divided into approximately 700 subcatchments, of these 25 percent were assessed as having their flows reduced to less than 40 percent of natural (high stress category), and another 10 percent as having their flows reduced to less than 60 percent of natural (moderate stress category) at these times. About 30 percent of sub-catchments were not assessed due to inadequate river flow data.

The 60% target is also generally consistent with the view of an expert panel of scientists from the CRC for Freshwater Ecology, the CRC for Catchment Hydrology and the National Parks and Wildlife Service reported in Watershed, February 2002, stating "There *is substantial risk that a working river will not be in a healthy state when the key attributes of its flow regime are reduced to below two thirds of their natural level*."

Because this target seeks to maintain or improve flow frequencies throughout the year it should be primarily judged using the whole of year daily flow statistics. However, river regulation and water extraction can impact on flows differently in different months due to the pattern of water abstraction, particularly irrigation demands and the seasonal effects of dams and their operations. Therefore the seasonal or monthly impacts of different water supply and flow rules should also be assessed. It is quite likely, for example, that environmental flow rules which seek to improve spring flows for bird breeding or fish spawning purposes may unintentionally worsen flow frequency in the remaining months of the year when other ecological processes may be important.

5 WHAT ENVIRONMENTAL FLOW MEASURES SHOULD BE CONSIDERED?

A common fault in relation to environmental flows is to limit consideration to measures which have explicit and limited environmental goals. It is often more critical that steps be taken to protect the current "residual" flow regime from further erosion or to set limits on extractions to ensure that there will be adequate residual flow once water use development has occurred. Residual flows are typically made up of (in the case of rivers controlled by dams):

- dam spills,
- inflows to the river from uncontrolled tributaries,
- rain rejection flows (irrigation deliveries that are not extracted due to local rainfall).

They provide the foundation flow regime upon which the more explicit "environmental flow" rules are built. If they are allowed to be eroded then the benefits of the explicit rules will be lost and ecosystem health will continue to erode. Without an overall extraction limit, water extraction will increase from the non-targeted flows to compensate for the impact of the specific environmental flow provisions.

Extraction limits should therefore be established to set an upper bound on the amount of water that can be taken from a river and the scale of the associated water development that can occur. These extraction limits can be set as simple annual limits in systems where there is little variation in water availability or water use from year to year. However, in most systems this is not the case and it is better to set these limits as multi-year or long- term averages.

In the past there was reluctance in NSW and other Australian States to set upper limits on extraction because there was a belief that:

- increased extraction was essential if there was to be increased economic development;

- future demand for water could be met from high flows with minimal environmental impact;
- an extraction limit would unacceptably impact on the rights of those with "water rights",
- an extraction limit would create inequity between those water users who have already fully developed and those who have not. (In NSW some licences which have been issued the right to take water have not yet been developed, but because the rights do not lapse, they could be developed in the future).

There is, however, increasing public and political acceptance in New South Wales of the need to place overall limits on extraction, typically defined as long term average annual volumes, in order to halt or prevent the environmental decline that is becoming evident in many systems. Clear specification of the limits to extraction are also essential to the water user for the clarification of water rights, the effective operation of a water market, informed business planning and efficient investment decisions.

Extraction limits protect the security of supply of existing licence holders by limiting the granting of new licences in a 'fully allocated' system. In the absence of an extraction limit over allocation and overuse can arise causing conflict within a community, devaluing individual entitlements and encouraging inefficient investment. There would be little motivation for efficient water use and the marginal value of water will generally remain low.

Evidence of significant environmental damage and the continuing erosion of supply reliability to downstream users in the Murray Darling Basin lead the Murray Darling Basin Ministerial Council to place an upper limit, known as a cap on total water diversions in the Basin at 1993/94 development levels (**Murray-Darling Basin Cap)**.

For many developed rivers where the environment is already evident, setting a cap on water extractions is not enough and supplementary environmental flow provisions are required to improve flows and rehabilitate the dependent habitats and ecological processes. Specific flow provisions may also be necessary in some systems prior to water resource development in order to ensure all elements of the flow regime can be maintained or mimicked.

In 1998, the NSW government designed and implemented, in consultation with local community committees, a set of environmental flow provisions for most of the State's major regulated rivers. These are currently being reviewed and revised while work is also underway to establish flow based extraction limits in the unregulated rivers across the State. These environmental flow provisions are designed to address the significant features of the flow regime which had been impacted by river regulation and/or water extractions. They will form a key component of a statutory water management plans which must also clearly specify the extractive water rights and water sharing arrangements.

Supplementary Environmental Flow Provisions in Regulated Rivers

A package encompassing four component environmental flow provisions has been developed for regulated rivers (rivers where flow is controlled via major storages and diversion works):

a) Translucent releases
b) Environmental Contingency Allowances
c) High Flow Extraction Limits
d) Supply Delivery Limits

a) Translucent Dam Releases

Translucent dam rules involve the release, under specified conditions, of some or all dam inflows coincident with their occurrence. These releases may only be triggered when inflows on their own or in combination with tributary flows occurring downstream of the dam fall within a prescribed flow range. They may also be subject to factors such as time of the year or the prevailing allocation levels for licensed water users.

The translucency rules are typically targeted at the flows which have been most highly impacted by development but may also target those flows which are effective in wetting specific parts of the river channel or floodplain (eg wetlands).

Translucency rules offer a number of advantages compared to fixed water allocations or other release rules which require the decision makers to hold water in storage until conditions are assessed as appropriate for subsequent release:

- translucency releases restore flow events as and when they would have occurred naturally. This ensures that the river functions as naturally as possible and synchronised with other environmental cues such as temperatures and nutrient inputs. The only way to ensure this is to closely match the timing, volume and rates of rise and fall of the release to the flows that would have occurred if the dam was not there.
- clearly prescribed translucency rules give dam managers greater certainty regarding their operations.
- translucency rules avoid the problems associated with subjective decisions on when environmental releases should be made, particularly the difficulties associated with monitoring and assessing downstream environmental conditions as a determinant of a release.
- translucency rules are preset, implemented for a period and can be objectively audited and reviewed. They are not subject to day to day pressures regarding the justification of a release either from conservational interests concerned that they must use it or lose it, or from other water users who may covert the additional water particularly in low supply years.
- translucency releases do not require the holding of an allocated volume of water for the environment in storage which can be more economically costly as it reduces the storage capacity available to other users or for storing available inflows.

b) Environmental Contingency Allowances

In some river systems, it may be appropriate to reserve some water in storage for subsequent release to deal with specific environmental problems if and when they occur. In this case, the purpose of the allocation is not to restore natural flow events, but rather to moderate downstream flow conditions, for example, to suppress a water quality or algal problem or to delay the recession of wetland water levels to enable a waterbird breeding event to be successfully completed.

In most cases, an environmental contingency allowance would involve a relatively small volume. In New South Wales the allowances have typically been from 20,000-50,000 megalitres per year which is equal to around between 2-5% of the volume allocated to agriculture. The allowances are however frequently not needed and there has been an ongoing debate as to whether such allowances should carry over or accumulate from year to year. This decision should probably depend on the types of environmental problems that are likely to arise in the river, their likely frequency of occurrence and the relative costs of increasing the annual allowance against carrying over the unused components.

In managing environmental contingency allowances it is important to be clear about who and how decisions to use the water will be made and to establish appropriate audit processes. It is probably best to leave such decisions to appropriately qualified scientists as the involvement of community and stakeholders in the decision making can confuse the decisions.

c) High Flow Extraction Limits

High natural inflows into regulated rivers have traditionally been treated as unclaimed or surplus water and irrigators have been allowed to take this in addition to the volumes they are annually entitled to take under their licenses. This has caused many irrigators to install larger pumps and off-river storages in order to benefit from these flows. As a result these high flows have been substantially reduced despite the fact that they may be the most ecologically valuable flows remaining instream.

Volumetric limits should therefore be placed on the extraction of high flows whether such extractions occur by direct pumping from the river or by the harvesting of water from the floodplain. These limits may include annual caps as well as event limits or shares.

d) Supply Delivery Limits

In regulated rivers a large portion of the allocated water supply is delivered downstream from the headwater storages during the irrigation season when river flows would have been naturally low for much of the time. This means that long distances of the main stem of these rivers as well as some regulated anabranches are carrying unseasonal high flows for long periods of time. In many cases these flows are held at or close to bank-full, saturating the riparian banks and/or inundating adjacent wetlands/billabongs for unnaturally long periods. These flows typically eliminate the natural water level variations and flow pulses which would otherwise trigger important ecological processes. At worst they will kill riparian and wetland plants, and cause local extinction of animal species which cannot tolerate long periods of inundation or stable water levels, and at the very least, they will reduce the food supplies, lower ecological productivity, reduce native fish numbers and advantage alien species. The damage often increases, the higher the supply flows are relative to channel capacity. For example, river flows typically break out into adjacent wetlands and start to saturate riparian root zones when the flow level is in the top 10 to 20 percent of the channel. Seeking to keep supply flows below this level should help to reduce the damage.

Environmental Flow Provisions in Unregulated Rivers:

In many unregulated rivers, there has been relatively little control on water extractions. In New South Wales, while irrigators have been licensed, their water licenses did not limit the amount of water that could be extracted. Furthermore up to half of the licenses are totally or partially inactive and as many of these are expected to become active, the impact on flows and on other license-holders will increase with the potential to cause significant problems in the longer term.

These unregulated rivers are often subject to significant fluctuations in flow on a day to day basis. At low flow times, particularly during the peak irrigation periods, extraction can impact significantly on flow and therefore on water quality and ecosystem processes. At higher flows, the demand is often only a relatively small proportion of the flow and many streams could tolerate additional extraction at these times. In some intermittent streams of western New South Wales, large pumps and on farm storages have already enabled significant volumes to be extracted from high flow events.

All unregulated river licenses have now been given an annual extraction limit. However such limits cannot protect the flow regime or individual flow events as the irrigation demand in these rivers are likely to be concentrated over a few months when flows are also likely to be low. Daily (or weekly) extraction limits provide a means to ensure that the volumes extracted from the prevailing flow are kept at a level which maintains ecological processes and habitats. Typically a daily extraction limit for a sub-catchment will be set at approximately 40% of the daily flow volume. This extractive volume is then shared amongst the license-holders in proportion to their annual limits. The establishment of daily or weekly flow extraction limits does however require the existence or establishment of a good flow gauging network and is therefore only proposed in rivers or streams where extraction is or is likely to constitute a significant proportion (at least 30%) of the low flow volume.

5 What about the Economic Impact of Environmental Flows?

Any discussion of environmental flows inevitably raises major concerns about the impact of such provisions on water availability and therefore on farm profits and/or regional economics. It is unfortunate that, in many examples of environmental flow planning, the initial focus has been on the hydrology and science with consideration of the operational and economic aspects left until firm proposals have been developed. This has meant that the process has often failed to explore the potential for complementary water management actions and mitigations, and has lead to adversarial claims over the level of economic impact being tabled at a late stage in the process rather than being properly addressed as part of the design criteria.

Estimates of the economic impact of environmental flow provisions have often been the source of the greatest disagreement and conflict. Industry advocates have often claimed substantially higher impacts than those put forward by either government or independent analyses. In the recent review of environmental flow provisions for the major regulated rivers in New South Wales, the irrigation industry estimated the impacts to be in the order of ten times those estimated by an independent consultant (ACIL 2002). There are a number of reasons for these differences including:

- The choice of an appropriate baseline against which the impact of environmental flows should be measured. Industry often quotes full development of the nominal volumes specified on water licenses as the baseline. However this is usually substantially higher than the volume of water actually available or used in reality and therefore is not an appropriate benchmark. For developed river systems the baseline should be the use under current rules. In relatively undeveloped systems, an optimal development scenario may be used to assess the opportunity costs imposed by different levels of environmental flows, but this should still be based on a realistic assessment of water availability and irrigator behavior. In either case the analysis should reflect not simply the last few years experience but rather a statistical pattern which will be driven by, among other things, random influences such as rainfall. Hydrologic tools such as the Integrated Quality and Quantity Model (IQQM) used in NSW, provide a useful tool for analyzing the patterns of expected water availability (and associated streamflow) under different management scenarios.
- Some assessments calculate any reductions in crop yields on the basis of the highest crop value whereas it is reasonable to assume that irrigators will, to some extent, limit water usage in response to reductions in water availability firstly to those crops or enterprises which earn the lowest return per unit of water. This is a process which will be aided by water trading, the rules that apply to carrying over the unused part of an annual water entitlement stored in a dam from one year to the next, and the ability to convert from one class of water supply reliability to a higher level of reliability (with appropriate reduction in volume). Increasing water scarcity will also tend to encourage greater water use efficiencies which will help to offset the reductions to some extent.
- Some assessments quote the impact in terms of the change in gross output rather than value-added which is a more relevant measure of economic activity.
- In measuring the flow-on effects of the impacts on the regional economy, the assumptions about multiplier effects can be significant and care must be taken to ensure that only net effects are considered.

The impact of changes in water availability on economic returns are generally quoted in average annual statistics. However industry advocates have increasing drawn attention to the worse case scenario effects which typically occur in low supply or drought years. The recent analysis of environmental flow provisions in New South Wales suggests that changes in water availability during a 1 in 50 dry year are much more pronounced than the average (by three or four times). However single drought years do not have a sustained effect on annual cropping, and any losses to farm income would be temporary and in many cases may be offset by carrying over water allocations and or profits from years of higher water availability. On the other hand, farm cash positions may be run down in drought years and credit sources stretched so that survival of farms can be disproportionately affected by the change in earnings. Assessment of environmental flow impacts should therefore consider both the long-term average impacts and the drought year impacts. In doing so it must, however, recognize that the capacity to manage the variability in any changes to water availability will depend upon the base supply variability, the sequencing of high and low supply years and the accounting or carry over rules and the temporary market opportunities.

6 CONCLUSION:

Dam construction, river regulation and the extraction of water can significantly reduce flows in our rivers. This reduction in flow will put the fundamental health and ecology of these rivers at risk. Managing and reducing these risks is not simply a case of allocating a volume of water to the environment or protecting or restoring one or two "critical" flow events each year. Ecological health and diversity is a product of the full flow regime, and therefore our management must seek to mimic, as far as possible, most of its attributes.

Recent experience in New South Wales has indicated that to maintain or restore the ecological condition of these rivers it is necessary to:

- consider the whole flow regime when assessing the impact of development, simple average statistics are misleading,
- specific, targeted environmental flow provisions are not enough, it is essential to provide a "residual flow" foundation,
- where possible, establish environmental flow measures prior to major development as it is very difficult to retrofit environmental flows after financial and social dependency has been established,
- consider protecting in the order of 60% of daily flows across the full flow range,
- specific environmental flow provisions can take a number of forms – the best option depends on the nature of the river and the form of the water resource development,
- where possible, establish objective, prescribed environmental flow rules which avoid subjective assessments of the prevailing environmental conditions and are often subject to ongoing social and political pressures.
- translucent dam releases and/or high flow extraction limits can effectively improve flow frequency, connectivity and the duration of critical events for bird or fish breeding etc,
- it is important to address the economic impacts hand in hand with the design of environmental flows and to select a realistic baseline, and to consider actions to foster improved economic returns from the use of available water supply including new water accounting methods that provide farmers with more flexibility regarding when they use their available supply, expansion of water trading opportunities, and improved water rights specifications.
- adopt more environmentally friendly operational practices in respect to supply delivery, dam and weir operation, airspace management,
- instigate complementary action to address other compounding factors such as removal or modification of barriers, rehabilitation of eroded channel or riffles, reinstatement of flood paths and inundation areas, reflooding of drained wetlands and creeks, mitigation of flow-related water quality problems, reduction in

thermal impact of storages, restoration of riparian zones, improved weed management.

Annual extraction limits are essential to protect the residual flows which are necessary to sustain the basic environmental processes. Specific environmental functions or habitats of value may be protected or restored through a range of supplementary environmental flow provisions such as:

- environmental contingency allowances
- translucent dam releases
- minimum end of system flows
- high flow event extraction limits
- daily flow extraction limits (unregulated rivers)

Wherever possible, environmental flows should be addressed as part of a comprehensive water reform or planning process which can ensure that water rights, allocation management and accounting, water use practices and the water market are managed to complement and mitigate any changes in water availability. Improved understanding of the factors affecting water availability, water use practices and risk taking, is as important as scientific knowledge in informing the sensible debate and design of environmental flows.

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