MANAGING WATER

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ABSTRACT

The current focus on water has arisen against a background of 30 years of neglect, particularly with scientific research. With drought highlighting the importance and value of water the response has been for sectoral interests to attempt to maintain or improve their position. This has exacerbated the situation and further eroded the rights of some landholders. The paper examines the current water savings initiatives in the context of the broad constraints by way of water availability, use and value. Potential developments are examined by way of the options and constraints to change.

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INTRODUCTION

A classic quote from Mark Twain is that everyone talks about the weather but no one does anything about it. That situation has changed with first scientists and then politicians deciding that they can now manage the weather. This represents a change from the weather being an ‘Act of God’ that we analyse, discuss and attempt to predict, to anthropogenic events that can be the responsibility of some. The change can produce a broad legal liability where previously there was none.

To date there have been no claims of ownership of rainfall, even with cloud seeding, and that provides protection from liability for damage caused by extreme events such as floods. However, some States are now claiming water as soon as it hits the ground. Some have always claimed ownership of water from household roofs, and water storage tanks were prohibited in some supply areas. One justification for the prohibition was an increased incidence of human disease with tank compared to piped water, but the main reason was to tighten the monopoly in the supply of water exercised by councils.

Water is essential for life, and all biota exercise control of essential resources, particularly humans. This creates an issue with separating the right to water from the land. For urban land use the separation could be argued on the provision of a more healthy and reliable water supply[1] but that situation does not arise with rural land use. Most rural landholders depend on water that falls on their land for their immediate use as well as the agricultural production that sustains them. Provision of an alternate water supply to rainfall with agriculture only arises with entitlements assigned from State appropriated water, as with irrigation schemes and extractions from rivers and groundwaters.

The term land has traditionally been used in a generic sense of land resources defined by the extent of a land area. Only minerals are exempt. In the initial development of Australia the land resource of value to settlers was the herbage that could be grazed by livestock, particularly sheep. Soil water grew the pastures but surface water was also needed for livestock. The only substantive change with the introduction of farming was the financial return from grain as farms traditionally combined wool and wheat. Some soil water previously used to produce herbage for grazing was used to produce grain.

Land cannot support life without the rain that falls upon it. It was therefore axiomatic that entitlements to use land for agriculture included entitlements to use the associated rainfall. Indeed, States previously promoted activities that increase the retention of rainfall on farms, such as the construction of dams. That situation has now reversed with some States implicitly claiming ownership of every drop of water that hits the land. This suggestion separates entitlements to water from the land despite the lack of a separate titleing system for such water.

While the rights of landholders to water from rainfall on their land are being eroded the rights of some individuals to community owned water have been strengthened. Legal title has been given to licensees to use water deriving remote from the landholding regardless of whether the licenses had previously been used or not, and without consideration of any over allocation of the water. This situation was compounded by an expectation that a water title guarantees access to the water.

The expectation of guaranteed supply for water through a water title is irrational as the water 'owned' represents a surplus from another area, and there is nothing to own if there is no

[1] Existing technologies make such an argument spurious.

surplus. A right to prospect does not guarantee the discovery of minerals, and a right to mine does not guarantee profitability. Similarly, ownership of a farm does not guarantee a living due to uncertainties in the weather, land management and markets. In agriculture such uncertainty is now sometimes addressed through a futures component of the market but with water this could be precluded by the very high level uncertainty.

The situation with water titles has arisen because of the focus on distribution and use of water with little regard to production. Sectoral interests are claiming fixed amounts of a commodity that is ill defined if only because of the variability in supply. Those interests expect the maintenance of an existing artificial situation. The only attention paid to producers of water is to expect them to maintain water quality and yields without any form of remuneration. That expectation is increasingly manifest as dictation.

Concerns for the conservations of streams and wetlands have resulted in the Australian Government buying water rights that were handed to farmers several years previously. While the rights were bequeathed by the States the associated titling was promoted by the Australian Government. That is, the community is paying for something that they previously owned that was handed to a select group at no cost.

The windfall gains to some farmers were often extreme as they were given title to water that had never been used and in many cases did not exist. In some cases farmers had been urged to increase entitlements simply to increase revenue for an agency. This occurred despite excess water allocation being known to cause environmental damage by mobilising salts.

Entitlements are categorised according to priority of supply. Highest priority is given to stock and household use and lowest priority to water that could become available if conditions are wet. The stupidity of bequeathing entitlements for all priorities of water is now highlighted by the very limited ability to supply high priority water with allocations to irrigation being as low as 10% of entitlements.

The recent changes to water management have been manifestly socially inequitable, and some changes have exacerbated the issues they were meant to resolve. Solutions now proposed revolve around expending large sums of money in doing more of the same where expecting to solve a problem by doing more of the same is one definition of insanity. This paper examines how this situation has arisen to identify potential means of stopping the lemming like rush to self destruction.

CONTEXT

Most life depends on the capture of solar energy through photosynthesis wherein gaining the CO_2 for photosynthesis inescapably involves a loss of water. This loss is to the individual and not the system as the water is recycled through rainfall. The loss is not absolute as the evaporated water is eventually returned to plants through the hydrologic cycle. The system is effectively a closed loop with insignificant losses globally but variable outcomes locally.

The fundamental issue for terrestrial plants is that water used by a plant through transpiration is not returned to that plant. The water recycling is external to plants hence the water use represents a loss to the individual.

Evolution is directed towards benefit to individuals wherein any benefit to systems derives from benefit to individuals. For water this is reflected in plants optimising their water use by way of maximising the CO_2 gained for the water lost. Water use by plants has evolved to be efficient. Evolution has not optimised the system as that would involve plants maximising their water use to take full advantage of recycling.

The practical implications are evidenced in societal responses to water supply and recycling. Each sector believes their existing rights are sacrosanct and should not be diminished by the requirements of others. City dwellers believe they have a right to dictate to those on the land to maximise water accessions and minimise costs. City dwellers believe they should not be subject to local water recycling that involves any degree of risk. The political dilemma involves reconciling individual vested interests with benefit to the society as a whole.

The above identifies that the issues relate to interactions between biota and their environment. The issues are intrinsically ecological and cannot be resolved using a mechanistic engineering approach or an artificial economic solution.

The Inevitability and Consequences of Change

Two basic tenants in biology are that things inevitably change and that changes are irreversible. In biology the number of organisms can increase exponentially through breeding, and population levels are controlled by the available resource. While humans have developed an appreciable capacity to remove resource constraints the current situation is that the number of people is increasing exponentially but the essential water resource is either static or declining. This situation inevitably results in negative change.

Previously the water available for use exceeded demand and this provided flexibility for administrators to address temporal fluctuations in water supply. That situation changed, firstly with over allocation, and then with the over use of water in key locations. The lack of flexibility in providing water associated with lack of control of production, and limited ability to change the pattern of distribution, triggered the introduction of a suggested market based system that incorporates monopoly suppliers and controls by governments.

While change is inevitable the human psyche has difficulty in coping with the associated uncertainty. This is reflected in the desire of conservationists and some scientists to preserve something they assign high value, as exemplified by the object of the Queensland Wild Rivers legislation being to preserve natural values. While people assign values nature does not. A desire for conservation has been replaced by a demand for preservation when preservation is only an option for museums.

The uncertainty associated with change creates a role for scientists as modern scientists fulfill the role of Shaman through predicting the future. Society pays scientists to reduce uncertainty in facing the future. The issue for society centers on the reliability of predictions, particularly when the predictions are designed to promote particular beliefs and/or pander to those providing the research funds.

The scientific method is designed to provide reliability through testing, but complexity usually prevents effective testing with natural systems.

> Einstein: When applied to complex systems the scientific method in most cases fails.
>
> Popper: Testing can be applied to parts of a system but not to the entire system.

Natural systems function through interactions thus test on parts of systems cannot reliably identify outcomes. In ecology this constraint is addressed using a deductive approach that examines the system as a whole. While this approach is used in astronomical physics an inductive approach is most common in science whereby outcomes are projected from studies on isolated components. While such extrapolations are inherently unreliable they form the basis of essentially all predictive modeling.

Ecology has been removed from the CSIRO Divisions of Wildlife and Ecology, Plant Industry, and Land and Water, hence ecology essentially no longer exists in that organisation. The focus of Cooperative Research Centers, which are meant to address priority research areas, is producing practical tools where this represents technology rather than science.

Such changes previously occurred with water research. In the mid 1970s water was out and salinity was in despite the irrationality of attempting to address salinity without understanding water. The multi-government Representative Basins Project designed to evaluate the nation's water resources faded away in the early 1980s. Despite the essential objectives not being achieved there was no replacement project. Attempts are now being made to resurrect water research following more than 30 years of neglect when in the 1960s Australia was the world leader.

Science is increasingly being used to transform beliefs into facts to justify the imposition of controls. Controls on water have increased markedly despite[2] the dearth of water research over the last 30 years, and the effective absence of any consideration of water production. Despite the lack of research the controls are identified as deriving from the best available science where best is determined by the source of the information rather than its content. It is therefore imperative to assess information on its merits rather than the source.

A Potted History of Water Management

The first settlers immediately identified fertility and water as limiting agriculture in Australia. Fertility was initially addressed by allowing stock to select the best pastures. Some addressed water by acquiring widely distributed landholdings in different environments and moving stock between them depending on conditions.

The push by governments for development progressively reduced the average size of landholdings despite this negating the conservative use of land to provide a buffer against droughts. The need to increase productivity to survive on small blocks was addressed by developments such as cropping, where the only buffer against drought was irrigation using water derived from elsewhere.

Dams became the solution, and the promise of a new dam was prominent close to elections. While ostensively justified on the value of agricultural production the dams were mainly political. For example, the Ord River scheme was developed to provide a new homeland for Israel. It was clear before construction that transport distances and lack of markets precluded commercial viability for the foreseeable future.

Dams became unfashionable as sections of the community questioned their commercial viability and decried their environmental impact. However, their effectiveness is evidenced in the statistics. Irrigation accounts for around 25% of Australia's agricultural production and delivers 50% of profit on less than 1% of agricultural land. The effectiveness of dams arises because of the high climatic variability.

The transition from more dams to no more dams occurred when the cost of water was based on the costs of capture and delivery without regard to the value it produces. For agricultural production the water was undervalued. Some with strong political influence realised the potential value of water resulting in the allocation of new irrigation licenses to individuals for

[2] It can be argued that it is because of.

community water that realistically did not exist.   This has been exacerbated in some situations by the private construction of large dams.

PATTERNS OF WATER USE

The natural patterns of water use were reflected in patterns of native vegetation. These patterns strongly reflect rainfall but were moderated by fertility and other climatic factors such as temperature and seasonality.

Some have recently suggested that water is not limiting in Australia, only its distribution and mode of use. This is despite Australia being the driest inhabited continent, and the patterns of native vegetation strongly reflecting water availability. Water is the prime limiting factor for biota in Australia where the limitation relates to the temporal variability as well as amount.

The influence of fertility is evidenced by most cropping occurring in inland woodland areas rather than in forest areas along the coast that have higher rainfall. The native forest vegetation in high rainfall areas limits the leaching of nutrients and this retention of nutrients is largely lost with annual crops. Cropping in high rainfall areas is essentially restricted to localised areas of high fertility soils that have a high capacity to store nutrients. Cropping soils with low nutrient retention in high rainfall areas incurs high fertiliser costs to replace leached nutrients. Moreover, the inevitable leaching commonly produces adverse environmental impacts elsewhere.

Water Balance Components

Rainfall is lost from systems through direct evaporation, transpiration, runoff and percolation. Evaporation is the direct evaporation of rainfall from soil and plant surfaces. Evaporation from plant surfaces occurs briefly during and immediately following rain but evaporation from bare soils extends into rainless periods.

Transpiration is the evaporation of water through plants associated with the photosynthetic production that supports most life. The transpired water is rainfall that has been stored in soils. As water stored in soils can only be extracted and used by plants is termed green water. Transpiration is evaporation but its separate recognition is necessary because of the control of transpiration exercised by plants.

Runoff is water from rainfall that flows across the surface of the soil into streams. Runoff is potentially harvestable by animals, including humans, and is currently the main component of stream flows. Such potentially harvestable water is referred to here as blue water.

Percolation is water that passes through the soil without being used by plants. Equivalent terms are through flow and deep drainage. The percolated water can potentially be harvested by humans where it contributes to groundwater systems and/or comes to the surface in streams.

Infiltration addresses the flow of water into and within soil profiles where most of the water that infiltrates into soils is transpired by plants. This potential use of soil water by plants makes it essential to discriminate between soil water and groundwater.

The boundary between soil water and groundwater is diffuse as it depends on the development of vegetation. Development of the soil profile depends on the balance between the infiltration of water and its extraction by plants. The depth of the soil profile is therefore determined by the effective plant rooting depth. Changes in climate also have an effect, as with a reduction in rainfall reducing the depth of infiltration of water into soils and thereby the depth of the soil profile. The soil depth is a functional outcome that derives through the interaction between the soil materials, climate, and vegetation.

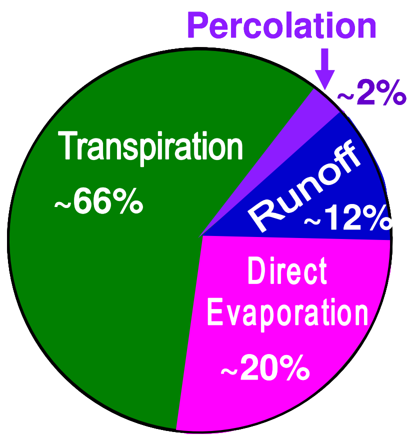

Fig. 1 General water balance for Australia

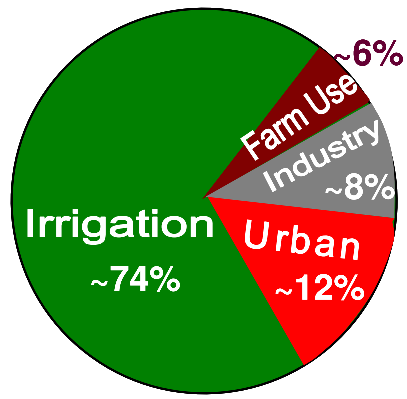

Fig. 2 General use of harvested water

General Water Balance

The very coarse figures available for Australia's water production and use provide a general context but they are by no means definitive. Information on Australia's water resources is variously presented and the figures are difficult to balance. Moreover, the spatial and temporal patterns in the production and use of water vary considerably. The water use estimates derive from the National Land and Water Resources Assessment (NLWRA 2002) where the values were mainly provided by State agencies.

Averaged across Australia most water is transpired (Fig. 1). Direct evaporation is the next largest component. Blue water, comprising runoff and percolation, constitutes around 14% of rainfall.

Around 12% of the continental average 460mm annual rainfall is estimated to flow in streams, but this does not discriminate between surface flows directly into streams (runoff) and water flowing first through the soil (percolation).

Caution is appropriate when interpreting these numbers because of the wide range of circumstances that have been averaged and uncertainties in the estimates. For example, the amount of percolation is less than the uncertainty in the estimate of rainfall.

Storages of Blue Water

The overall balance appears good with only 5% of surface flows being harvested, but some regions are likely overexploited. For example, 45% of all irrigation occurs in NSW.

The volume of storage in groundwater systems is not given as it is suggested it is irrelevant. The reality is that it is effectively unknown, but it has been estimated as being more than double the annual rainfall. The volume of harvestable groundwater is given as being 27,780 GL and this represents the estimated annual recharge to groundwater systems. However, at equilibrium net groundwater recharge is zero as recharge into groundwater systems equals outflows elsewhere. At equilibrium groundwater flows serve only to redistribute water and a natural equilibrium is only prevented where there are underground reservoirs that have yet to fill.

These considerations address the representation of groundwater in the NLWRA but there are other representations of groundwater systems. Some consider there are unfilled underground reservoirs. Others suggest that water can be generated within the ground where this is referred to as primary water. Occurrences of primary water could be important in determining groundwater availability but neither the occurrence of primary water or the magnitude of unfilled reservoirs will be assessed given the attitude expressed in the NLWRA that the volume of groundwater storage is irrelevant.

Fig. 1 Continental water use estimates.

		Total	Usage
	Allocation	GL	GL
Total		3,226,500	24,000
Surface runoff	12% of rainfall 80% of use	387,184	19,000
Large dams	Storage 20% of annual runoff Delivery 5% of annual runoff Delivery 80% of total water use	80,363	19,000
Farm dams	Approximately 1% of use	7,100	?
Groundwater	18% of recharge 19% of use	27,780 sustainable	5,000

The potentially harvestable groundwater has been determined from estimates of groundwater recharge where groundwater recharge is usually estimated from water balance. However, for most of Australia the estimate of groundwater is less than the error in estimates of rainfall, and much less than errors in estimates of evaporation. This approach has very low resolution and reliability.

Concerns have recently been expressed that exploitation of groundwaters threatens groundwater dependent ecosystems. This suggestion is axiomatically correct but does not identify the proportion of groundwaters associated with such systems. There is no differentiation between percolation that contributes to different parts of the system. For example, while some percolated water contributes to streams, lakes and swamps, most likely does not have surface expressions. Also, there is no discrimination between ground water flowing in fractures or lying static in basins. Applying the precautionary principle this deficiency in knowledge would result in no groundwater extractions because they might adversely impact on groundwater dependent ecosystems when most groundwater storage is unconnected.

The inescapable conclusion is that the availability of potentially harvestable groundwater is not well known.

The availability of surface water is better known than for groundwater but is still not well known, as illustrated by some estimates of basin yields being revised by almost 50% since the 2002 NLWRA. From a scientific perspective this situation is inevitable given the size of the country, the remoteness of most areas, and the limited resources available for measurement.

However, the implications are generally manifest through application of the precautionary principle by administrations where this justifies basing decisions on ignorance. We can't change allocations other than to reduce them as we don't know what the changes might do.

General Use of Harvested Water

On average only 6.5 % of the blue water is used where this is around 0.75% of rainfall. The dam storage capacity of 20% of runoff is necessary for the dams to be effective in providing water during droughts.

Most of the harvested water is used for irrigation (74%, Fig. 2). That is, most of the harvested blue water is used as green water for agricultural production. At 12% urban use is higher than the 8% for industry.

The estimate of 6% rural use for domestic and livestock contains high uncertainty. The number and capacity of farm dams are difficult to estimate. Also, the amount of water that a dam harvests depends on several factors that cannot feasibly be determined for most dams. This is compounded by the low water use efficiency of most dams whereby more than 80% of the water can be lost through evaporation. Most farm dams are inefficient due to their high surface area to storage volume.

VALUE PLACED ON WATER

Green water used for irrigation is now assigned a monetary value related to its use in growing plants to produce food and fiber. This approach is applicable with irrigation but with dryland farming the value of rainfall is integral to the value of the land as there is no means of reliably quantifying the amount of green water, or of separating the value of green water from that of the land. Factors additional to water such as fertility and temperature contribute to the productivity and profitability of land, and there is no practical means of determining the separate effects of the different factors.

All blue water is owned by the States. Regulation is by State agencies, and community supplies are managed by public utilities (State or Local Government). Private extraction is landholding specific and paid for by the landholder, thus historically the only sale of water was by utilities that had a monopoly within their supply district. With these arrangements the only value placed on water relates to the costs of administration, distribution and use. No intrinsic value was assigned to harvested blue water even where it was used in irrigation to grow plants.

The current situation with blue water is confused as water management varies between States, and the effects of recent changes to water management are evolving. Water titling was meant to establish a market where the cost of water reflected the value deriving from its use but this has been stymied by two main factors, the monopoly held by suppliers and the high uncertainty in the availability of water.

While sometimes ostensively corporatised, the organisations controlling water supplies to cities and irrigation districts function similarly to before through being monopoly suppliers. In irrigation districts greater local involvement has produced greater parochialism in retaining control of the water resources. This parochialism is reflected in a high premium being placed on water sales that leave a district. This desire to restrict the transfer of water has resulted in a High Court challenge where success of the challenge would raise more issues than it solves.

The 2006 drought resulted in the NSW Government freezing irrigation water supplies. Associated impacts included loss of water that had been purchased for several hundred thousand dollars, loss of water left in a dam the previous season as insurance, and a universal waste of water due to the timing of the decision. The decision was announced after the first irrigation applications whereby the lack of ongoing supply precluded the growing of a crop. The initial irrigations represented a cost where use of the water served no purpose.

The losses arose through not being able to access entitlements. An entitlement purchased to address a shortfall for the season provided no water, with the unavailability of water being announced shortly after the purchase. With the dam, a saving of water in one season could not be transferred to the next.

The introduction of water titling was based on the assumption that market forces would lead to efficiencies, more profitable use of water, and improvements in the surety of supply. Natural and social factors militate against these changes occurring. The natural variation in rainfall largely determines the supply hence there can be no surety. Redistribution of the available water is effectively restricted to occurring within drainage basins given the use of rivers to transport water. It was therefore suggested that it would better match use with supply with titles from over exploited catchments being transferred to those deemed to have unutilised capacity. Such belief in the ability to solve social issues through economic rationalism has no substantive basis, as illustrated by the cost penalties imposed on transfers of water out of districts[3].

The most profitable use of water is to use entitlements to increase the capital value of land. Most profit from transferred water arises through the increased capital value rather than production as on average around 60% of the profit from agriculture arises through capital gains. As for efficiencies, the water traded is a small component of that used hence its impact is at best marginal. These constraints existed before the introduction of water titling and should have been known.

The key issue associated with valuing blue water can be illustrated by reference to the 12% of harvested water used in cities and townships. The water is essential for people to exist but the water is not used in production and so does not return a profit. The water cannot be valued on the profitability of a productive use. The only tangible basis for valuation is the service cost of delivery, as has historically applied.

The business and hence market approach in this situation is to value a product on what people will pay where this is designed to maximise profitability, and this is already occurring. In the ACT excess water use above the base allocation is charged at a higher rate than the base allocation. With the normal business model applied in industry the excess should cost less because of the fixed capital costs of the infrastructure and essentially no change to operational costs.

A similar situation arises in the Sydney catchments where the internal but not public position was that the increasing demand could be addressed by raising prices. In the meantime water pressures have been reduced because of the declining infrastructure and politicians have promoted expensive short term solutions in an attempt to placate residents. While most if not all of the land needed for the long planned Welcome Reef Dam on the Shoalhaven River has been purchased it is essentially never mentioned.

[3] The issue relates to discriminating between benefit to the individual and the society.

This connivance by corporatised water authorities is possible because of their monopoly position. Their performance evidences the need for the public to retain control of the essential resource through ownership by Governments. It also evidences the need to remove their monopoly status: the existence of the monopolies prevents the introduction of more cost effective alternatives such as autonomous water systems for villages. The potential elimination of the monopolies is most advanced in Queensland where individuals can sell water they harvest, and has commenced in NSW where individuals can now sell processed waste water. There can be no genuine market value for water and hence no self regulation of prices until the monopolies are eliminated.

Value for the Conservation of Biota

Many of the water reforms have arisen because of the suggested need for environmental flows. Suggestions of overuse have arisen from those identifying a need to increase water flows in rivers to maintain a particular natural feature. The general thrust of the argument is that the situation in the recent past should remain into the future, where this represents preservation.

The occurrence of change precludes preservation as an option and this can be illustrated by Lake George. With the first recorded observations the lake contained woodland but with all the trees dead. The extensive occurrence of large trees indicates that the lake had not contained water for an extended period prior to 1800. Lake George has been a lake on several occasions since then and was regarded as being full in the 1960s. It has effectively been dry during the current drought. These changes to Lake George occurred without any extraction of water.

The question this raises is what condition should be preserved, woodland, grassland or a lake. Some locals opted for the current grassland condition in suggesting that that the Lake warranted world heritage listing as grassland. However, there is no option for managing the area as either a lake or a grassland as the outcome now depends solely on fluctuations in the climate.

The situation is most clearly evidenced by attempts to regulate levels of stream salinity without any knowledge of what they naturally were, and without regard to the implications for the land. The objective it to maintain an artificial condition in part of the landscape deemed desirable for a particular reason without regard to the system function. With salinity the objective reflects the use of rivers to transport irrigation and drinking water, and it disregards the natural function of streams in draining the land.

Assuming that conservation objectives are clear the issue remains of how to value the environmental outcomes. There is no monetary return from water used for conservation but without water the existing natural systems would cease to exist. However, a prior system is always replaced, so when one form of environment is lost another is gained. Issues involved in valuing the changes are whether a particular environment is considered priceless, or whether the net change can be valued by comparing the prior and new situations. Is the value of the environment being addressed absolute and supersede all other considerations, or does the value relate to the difference between the initial and replacement environments?

As these issues have not been resolved the conservation value represents a human value judgment having a poorly defined basis. Environmental flows are political rather than scientific.

Blue Water

The conservation focus is on blue water because such water is:

- limited in availability
- highly localised
- usually contains distinct biota restricted to that environment
- supports large populations of biota due to the enhanced fertility arising from the accession of nutrients from elsewhere.

While there is no question as to the desirability of preventing the loss of species the issue is what should a particular water system look like. For example, should flows be maintained in the Murray River when naturally it frequently became dry?

It is unclear whether the intention with conservation is to artificially maintain existing populations, many of which are currently artificially high, or to address the survival of species. Differentiation between these objectives is essential as maintenance of populations involves preservation whereas the survival of species is best addressed by way of the natural cycles of change.

The Snowy River Scheme was designed to maintain flows in the Murray River through a 7 year drought. This, and the occurrence of reasonably wet conditions, resulted in the Murray River always flowing within personal experience. This has developed an expectation that it always will flow, and the belief of some that it always did. Schemes to maintain flows usually seek to produce and maintain unnatural conditions.

The scientific question revolves around what is meant by the environment. If it is the specific complement of physical and biological components that currently exist in a location then the object is preservation of an existing and often artificial situation. If it is something else then it is not clear what it is hence the need for environmental flows cannot be rationally discussed.

An alternate approach to specifying an amount of water thought necessary to maintain the environment is to examine the impacts of land use including water harvesting. There is no doubt that most waterways have been degraded, many severely. Introduced species such as carp, pigs and salvinnea have had major impacts, but most degradation has arisen from grazing causing erosion by increasing the velocity and amount of surface runoff. It has arisen through an increase rather than decrease in flows that degrades the quality and duration of flows.

Water harvesting for agriculture has had an adverse impact on some systems dependent on floods but its general impact has been to increase the extent and persistence of surface water. For many water dependent species such as waterfowl this has allowed the maintenance of much higher populations than naturally possible. This has been promoted by the increased supply and reliability of food from irrigation areas.

The conclusions are that most of the adverse impacts of land use on waterways do not arise from water harvesting and that developments associated with water harvesting have had a beneficial impact on many water dependent species.

Green Water

The conservation aspects of green water are seldom considered despite the importance of soil water for virtually all biota. For plants some implications are obvious as production and survival depend on soil water storage. However, the degradation in soil water largely arises through a loss of soil organic matter and is therefore associated with a loss of fertility. A loss of fertility adversely affects both plants and animals.

The decline in soil water infiltration and storage associated with the ubiquitous soil degradation has produced widespread changes in vegetation, as with natural grasslands becoming shrublands or shrub woodlands. From explorer's records plant communities that were once widespread have been lost. The effect on fauna is personally poorly known but there is abundant evidence of change. The distributions of many species of birds has progressively been extending into areas of higher rainfall.

The changes in the distributions of biota are most readily related to rainfall but water and nutrient availability are linked. As agriculture has been concentrated on the more fertile soils the maintenance of patches of remnant vegetation having high fertility has become critical for conservation.

The importance of fertility for conservation is seldom identified for terrestrial systems where this contrasts with marine environments where fertility is always identified as the key factor. Studies identify that the native fauna is now highly concentrated in areas of high fertility, and that small patches of land having high fertility are priority conservation areas. Pockets of native vegetation on high fertility soils have become refugia for native fauna.

The impacts of land use on green water have all been negative while for blue water they encompass positive and negative outcomes. As the negative impacts on green water have adversely impacted on blue water the priority in conservation should logically be addressing green water.

WATER SAVINGS

The current focus on water savings derives from the realisation that the available water is finite even if we don't know what it is, but it has been strongly driven by a push to return irrigation allocations to the environment. As irrigators expect to maintain existing levels of production the objective is to achieve the same or improved production with less water. Depending on the cost of the changes this can translate into improved profitability.

The water management strategies evident with native biota differ from the human strategies. Natural developments seldom address a single factor, as with particular physiological characteristics of plants and animals commonly addressing both water and nutrients. For changes in the characteristics of plants and animals to be viable they must address the overall functioning of the organism. In contrast, developments in blue water management involve the use of engineering infrastructure to incrementally address issues as they arise. The human approach is typically piecemeal rather than holistic.

The implications of incrementally addressing individual factors are illustrated by the Pyramid Hill salt interception scheme. A short section of a shallow natural drainage line was transformed into a deep straight channel to increase the rate of flow of water for irrigation. Salt then seeped into the deep channel during winter when the channel was empty. Concern for contamination of the distant Murray River through its application in irrigation led to the installation of groundwater pumps at intervals along the channel bank to remove the saline groundwater. The saline groundwater disposal was addressed using evaporation ponds. The salt production was promoted as being commercial but was not viable despite development of the facilities using public funds. The Murray Darling Basin Commission (MDBC[4]) assigned salinity credits to the harvested salt thereby assigning monetary as well as environmental value to the salt. The Engineers Society awarded the development their annual environmental prize.

At face value this development may appear reasonable but the salt would not naturally have reached the surface let alone the Murray River. The 'problem' solved by infrastructure development was self generated and should never have occurred. Engineers were paid to solve a problem they were paid to create which facetiously could justify the self-assigned award.

Administrators justified past expenditures by further public expenditures identified as providing environmental and commercial benefits. Similarly to the engineers, self assessment was used to determine the environmental benefits by way salinity credits. The salt production was not commercially viable even when quarantined from the full development costs. The social issue is the presentation of a costly but useless exercise as being environmentally beneficial and commercially viable to justify the high public expenditure.

While this example represents an extreme it is not unique. As the administrative approach with the Australian Government's current water initiative is the same as occurred with dryland salinity it identifies the need to examine activities addressing water savings to assess the extent to which they provide real gains rather than camouflage the adverse impacts of prior activities. Expenditures are addressing past mistakes with little if any consideration of long term development.

Blue Water

The focus with water savings has been on reducing losses in the distribution and use of blue water where this mainly involves increasing the water use efficiency of the delivery system. The methods involve engineering technologies, such as replacing distribution drains with pipes, the capping of bores, and the replacement of flood irrigation with drip irrigation.

The only apparent 'scientific' reason for the focus on blue water is the suggestion that water being used for irrigation is needed to maintain the environment. At a general level the irrationality of this focus is that water in streams and groundwater represents a small part of environmental water as most environmental water is transpired by plants.

Politically there is a need to be seen to be doing something when blue water becomes limiting as governments exercise an appreciable level of control. The community expects rapid solutions hence the proposed solutions almost invariably involve modifications to existing systems using existing technologies. The solutions inevitably involve doing more of the same.

Efficiency gains must be coupled with new developments to be viable as improving efficiency alone leads to extinction. However, given the years of neglect in conducting research, the options to increase efficiencies are limited and potential new developments cannot be identified. The current water initiatives do not have the essential combination of new developments and improved efficiencies to be viable.

Green Water

Green water has not been considered in current initiatives addressing water savings. Reasons include a suggested political need to focus on gaining most benefit from the limited blue water, which reflects the lack of community knowledge or concern for green water, and the

[4] The MDBC is an Australian Government authority designed to achieve coordination across States. Its structure produces strong State control.

suggestion that green water savings are intangible. This last point arises despite the potential water savings for around 75% of blue water being manifest in the same way as for green water, i.e. by way of agricultural production.

While the outcomes with blue and green water savings may be the same there are significant differences that promote acceptance of blue water savings and limit acceptance of green water savings. Blue water savings can be simply calculated and expressed, and the saved water can potentially be traded and/or reallocated. Blue water savings can be conveniently if not effectively addressed using economic models. While the potential benefit from green water savings can readily be calculated any predictions of monetary gains contain considerable uncertainty, and the savings cannot be traded or reallocated.

The current hurdle in gaining acceptance for green water savings appears to relate to the treatment of water as a commodity with an intrinsic value rather than its market value deriving from what it produces. The situation is analogous to the assignment of an intrinsic market value to currency. This appeals to some but adds nothing to its value. This anomalous situation is reflected in presentations at a Water Commission sponsored conference discussing market forces in water management that did not consider the reality of monopoly suppliers and government controls.

Given the relative production from irrigated and dryland agriculture, a 1% saving by way of beneficial use of dryland green water equates with a 130% saving in the use of the blue water for irrigation. The potential water savings are much greater for green than for blue water. This arises because of the very large amounts of dryland green water compared to the harvested blue water.

Green water savings are achieved by improving the soil, primarily by increasing the soil organic matter. For levels of organic matter of interest for agriculture the general gravimetric increase in soil water availability to plants is around 2.3% for a 1% increase in organic matter. A 2% increase in soil organic matter over a depth of 300mm, which is readily achievable in agricultural soils, increases the static soil water storage by around 15mm.

The consequences of this increase in storage are greater than indicated by the 15mm because the soil water storage is dynamic. The surface soil usually wets and dries many times throughout a year. With five wetting and drying cycles over a year a 15mm increase in water storage could potentially produce a 75mm increase in the storage of water available to plants. However, the realised water savings are considerably higher again due to the increase in fertility associated with the increase in soil organic matter increasing the efficiency of water use by plants.

A productivity gain of 50% in dryland areas with a 600mm rainfall provides an effective water saving of 2 ML/ha yr. Such figures can be used to calculate the potential water savings achievable by improving the soil in agricultural areas but the figures have little value other than to indicate that the numbers are extremely large.

The use of green water by vegetation can contribute to blue water through indensation. Development of the soil structure under perennial vegetation, and the storage of indensed water in soils, increases the percolation of water through soils. The only known figures identify a change from 20% runoff to 20% percolation where percolated water has higher quality and persistence than runoff. Moreover, the improvement in water arises with a large increase in production by the vegetation, which with cell grazing can be a factor of 4. There is a very large potential to increase production and water outcomes by focusing on green water.

Embedded Water

Calculations have been used to compare the water used to produce different foods, termed embedded water. The water used for production is compared with the residual water contained in the food. A low ratio of production to residual water is considered to in some way be beneficial, thus low embedded water is considered to be good and high embedded water bad.

The identification of embedded water mimics the calculation of the energy used to produce products, but the calculations are of uncertain value as they treat water as a non-renewable resource when it is essentially fully recyclable. Moreover, calculations typically address irrigation water and do not include dryland farming. Also, there is no single universally applicable performance measure to provide valid indication of benefit (e.g. water content, fresh or dry weight, protein or carbohydrate, total or usable energy, productivity or profit).

Transpiration

The upper limit for embedded water is set by the ratio of water transpired by plants compared to the water they store. For melons and capsicums this is around 3.4 and 1.7% respectively[5]. As only a portion of the plant is harvested the embedded water in the associated food is appreciably less, thus all food contains a large amount of embedded water.

The amount of embedded water in plants depends on water use efficiency which depends on the favourability of the growing conditions. Horticultural crops are grown under highly favourable conditions hence the above figures reflect an optimum.

Wheat

Wheat at 5 ton/ha with 20% moisture contains 1 ton of water, which is equivalent to 0.1mm of rainfall on 1ha. As this is the maximum crop yield for 500mm of water, wheat grain contains less than 0.02% of the water used to grow the crop.

Wool

Wool effectively derives from dryland agriculture as sheep only graze around 0.4% of irrigated pasture. 80% of sheep occur in the pastoral zone thus, while wool contains some embedded water by way of water they drink, most embedded water derives from the vegetation they eat

The 65.3 M head of sheep in the pastoral zone produce 575 kton of wool on 69 Mha (NLWRA 2002). Assuming 50% transpiration by pasture and 250 mm annual rainfall, the wool contains around 0.0007% of the water used to produce it. The embedded water for wool is high.

The notion that only blue water is of consequence has resulted in the suggestion wool can contain little embedded water. However, the embedded water in products deriving from herbivores is generally much greater than for products deriving directly from crops because of the inefficiencies in conversion.

Wine

Wine has low embedded water as viticulture uses minimum water and the product has high water content. Yields of wine grape vary considerably from around 5 to 20 ton/ha, with high

[5] With 1% water use efficiency the embedded water is 100 times the water in the product. The lower the water use efficiency the higher the embedded water.

quality wine being associated with low yields and high water use efficiency. With 12 ton/ha of grapes at a moisture content of 90% produced with 500mm of water, the grapes contains around 0.24% of water used for production. Around 80% of the grape converts to wine, and washing during production uses an amount of water equivalent to that in the wine. Wine contains around 0.1% of the water used to produce it.

CHANGE

Blue Water

The main constraints in managing blue water are:

1. The known water resource is already limiting in some areas
2. The demand for water continuously increases due to the increasing population
3. The spatial patterns of rainfall and evaporation result in areas with excess water but most have a deficit
4. There is high temporal variability in the availability of most water
5. Water is essential for life, directly for consumption and indirectly for food production
6. Land use has degraded the blue water by:
    - decreasing the persistence of flows
    - decreasing the water quality
    - through desertification, decreasing the water supply.

The drivers for change derive from points 1 & 2. The blue water resource is limiting in some areas and that situation will exacerbate due to the increasing demand.

The main options for addressing points 1 & 2 on their own are:

a. Control the population
b. Transfer water from areas with a current excess to those with a deficit
c. Transfer some of the demand to areas with a water surplus

The last two options take advantage of point 3, that there is spatial variability in water availability.

The population cannot yet be substantively managed so option (a) is currently of theoretical interest only. The transfer of water from areas with a surplus to a deficit already occurs, and the most feasible developments have long been implemented. More costly and likely marginal options have been proposed but have not been rigorously evaluated. Most involve transporting water from the north to the south.

For agricultural production, which uses around 75% of the harvested blue water, the practical option is to transfer production to areas with a water surplus rather than transport water across drainage basins. With crops such as melons the water needed to grow a crop is more than 100 times the water in the produce. Even with wine with very low embedded water the ratio is less than 1000:1. It is more practical to transport produce than the water used to produce it.

The main factors limiting development of northern areas have been the lack of markets and the costs of transport to markets, as evidenced by the Ord River Scheme. However, development of the Asian economy has created a market for produce from northern Australia, where most of the water surplus has always existed, and the market is much closer to the production than established irrigation areas to the south. Experience with the Ord has developed much of the expertise needed to profitably grow crops in the tropical areas. However, their sustainability has not been evaluated.

Substantial social barriers exist in realising such changes. One is the availability of people prepared to live in such areas which, compared to the south, have limited infrastructure and facilities. Moreover, the climate is deemed undesirable by most Australians. Another barrier is the resistance by established interests in the south to expenditures on competing developments in the north. Yet another is the suggestion that there is no water surplus in northern Australia, which arises from invalid modelling as well as suggestions that all of the blue water is needed to maintain the environment. The irrationality of the Queensland Government's Wild Rivers Legislation evidences the obstacles to change posed by some environmentalists.

Point 4 represents an additional constraint that strongly affects the viability of developments. The profitability of irrigation in the south largely derives from the buffering dams provide against climatic fluctuations. Any development proposal must address this constraint by ensuring that either:

a. The water being harvested is reliably available every year.
b. Sufficient storage is provided to maintain the desired supply during extended periods without rain.
c. Access to water from multiple sources ensures the maintenance of the desired water regardless of fluctuations in rainfall.

Accessing multiple water sources can take advantage of spatial variations in rainfall but the approach is most efficient where it integrates surface and groundwater resources. Generally across Australia groundwater has been used to provide water in locations where surface water is limited or unavailable. However, a key advantage of groundwater is the high storage and hence high buffering capacity against fluctuations in rainfall. Groundwater potentially provides the best form of drought reserve for blue water as, while losses occur, it is not subject to the evaporation that occurs in surface storages.

Point five produces a dichotomy in valuing and managing water that is central when addressing most management and hence development issues. The value can be based on the value of production from water and this allows management using markets. However, as water is essential for life, and there is no replacement or substitute, its value can be absolute and this necessitates control by governments.

A lack of discrimination between these values is usual and it results in proposals that are illogical when closely examined. It has frequently been suggested that water should be piped from the north to the south where this would transfer water from areas with a large but highly seasonal surplus to areas where there is an existing high demand. The inference usually is that the water is needed for people but, given that 75% of blue water is used for irrigation, there is already abundant water for people in the south. The deficit arises from the desire to maintain or expand irrigation in the south and the suggested need for environmental flows. The logical change by way of costs and efficiencies is to transfer some of the irrigation farming to the north rather than bring water to the south.

Issues associated with point 6 are addressed under green water.

Green Water

The main constraints in managing green water, apart from most not knowing what it is, are:

1. Some States assuming they own every drop of water that hits the land.
2. The focus whereby water is only assigned value where it contributes to blue water.
3. The lack of appreciation of the importance of green water for human nutrition, conservation of biota, and the amount and quality of blue water.

As green water has to be treated holistically the management will differ from the approaches currently used for blue water. Incremental implementation of piecemeal solutions to the most pressing problems is not a viable option, as has been demonstrated by broadscale agriculture. Change can be incremental, as is already occurring with the general adoption of minimal and zero till in agriculture, but the vision and planning need to consider the entire system function.

Dryland salinity provides an example whereby a simplistic and invalid explanation of how it arises was used as the basis for developing practical tools and expending large sums of public monies. It was assumed that the science was known hence the focus was on the development of technologies that address the symptoms. Governments identified an official model and only funded complying activities. The water initiatives are following this path despite the obvious failure of the salinity programs.

With rational analysis dryland salinity arises through soil degradation, and it reduces the availability of water in a water limited environment. However, its greatest impact is likely the loss of fertility in the soils that deliver the salt. The adverse impacts of dryland salinity are much greater than suggested by the emotive reference to 'white death' as they encompass the entire landscape.

Getting green water to be treated seriously has been difficult given the current paranoia with blue water. This has been exacerbated by ill conceived representations on the environment that assign values to personal beliefs and attempt to justify the belief on the basis of science, as reflected in the expectation of preservation.

Suggestions that soil water can in some way be separated from the land title serve to produce inappropriate management of the land. Land managers are expected to manage land to address unrealistic perceptions as to what streams should look like. The land is being sacrificed to artificially maintain streams, as is most of the biota. Even ecologists have been failing to consider the relationships between their study interests and the functioning of the total system.

With expected business developments green water will eventually have to be addressed as overseas markets increasingly expect agricultural produce to be 'clean and green'. There is a commercial need to reduce inputs of chemicals and improve the natural functioning of agricultural systems. However, the evolutionary progression will be primarily determined by the constraints imposed by desertification produced by agriculture. Considerations of chemicals are irrelevant when there is insufficient water to produce food. Given the role of indensation in supplying water, future requirements for food can only be addressed by repairing the soils and vegetation.

Evolutionary Constraints

Humans are subject to the same basic evolutionary constraints as other biota hence change can be assessed in an evolutionary context. The basic constraint is that evolution is directed towards benefit to individuals and any benefit to a system derives from benefit to individuals. Humans are communal and governments are meant to promote the community good, but the prime focus of individuals is personal benefit. As noted in the introduction, the dilemma for politicians is how to reconcile personal gain and community good, particularly where there is a desire to promote personal rights and freedoms.

The main effect of this constraint is the suppression of change by vested interests, and this situation is ubiquitous throughout societies. For the environment this arises with environmental scientists promoting the preservation of systems they study as that provides their claim to fame. Conclusions are made in isolation so as to promote a particular view despite the scientific requirements for objectivity and clear definition of the limitations imposed by boundary conditions. For water this constraint is reflected by the cost penalties imposed when transferring water titles out of an irrigation district. The removal of monopoly arrangements for suppliers will be resisted. Change has greatest chance of being implemented where it promotes existing controls, as evidenced by the titles for irrigation water.

There is no simple means of addressing these constraints but there are factors that can promote the implementation of change. The obvious one is to provide personal benefit without regard to the community, as occurred with water titles. While this approach can ensure rapid implementation it creates more problems than it solves.

The approach that has been adopted with global warming is the threat of apocalyptic change unless more benign changes are made now. This approach is generally unsuccessful as the high failure rate of predictions results in the ‘cry wolf’ syndrome. The temporary success of the approach with global warming evidences an inevitable undesirable outcome with people joining the bandwagon to promote personal benefit. Fact and fiction become one in the scramble by scientists to obtain benefit from an issue assigned high priority by society.

The ultimate stimulant for change arises when the status quo is detrimental to all, but the most desirable situation is where the change is beneficial to all. However, the disconnect between the stimulant and outcome means that changes need seldom be beneficial. The issue is how to turn negative drivers into positive and beneficial outcomes.

A key role for scientists in society is identify new options and thereby increase opportunities for generating universally beneficial change. Another is to provide rational analysis of known options to select the most beneficial. Scientific research is essential in achieving beneficial change, however, where scientists succumb to promoting benefit to themselves and their funding source they generally suppress rather than promote beneficial change.

The administrative approach to these issues has been to effect change through the imposition of controls, and this is most apparent with the environment. The Queensland Wild Rivers Legislation imposes constraints on landholders to elicit votes from cities and, when those affected attempted to implement their legal right to oppose the constraints, that right was removed. Regulations for implementation of the NSW Native Vegetation Act explicitly identified that the results and decisions of agency scientists could not be questioned by anyone, including the courts. Basic legal rights of individuals are being removed by governments[6], for votes in Queensland and additionally for Australian Government funds in NSW.

Attempts to separate green soil water from the land title represent the removal of a long held right. The question is the extent to which subjugation of part of the community through application of authoritarian control can continue. The suppression was initially successful as it targeted a small part of the population, but there have already been relaxations designed to

[6] While some attempts to remove rights are unconstitutional, as with attempts to prevent redress through the courts, it is difficult for individuals to assert their rights.

appease. The relaxations are likely too little too late as the experience throughout the world is that such authoritarian actions are eventually overridden.

CONCLUSIONS

Along with organisational constraints the neglect of water research over the last 30 years has resulted in an attempt to redress the impact of water shortages by patching up the existing system. There has been no coordinated plan or any substantive examination of alternatives as the examination of alternatives is severely limited by the lack of scientific research.

The allocation of water titles bequeathed public property to vested interests and so was not resisted by the beneficiaries. The allocations were not resisted by the population because of the lack of provision of the context needed to make a realistic assessment. This situation continues with new water initiatives wherein public funds promote private benefit. While this can sometimes be justified in terms of public benefit there are additional changes that provide benefit to some by removing long established rights of others without any compensation.

This tendency for governments to attempt to achieve outcomes through control should be of concern to the community. It is of particular concern where governments deliver services against regulations they develop and police, especially where others are excluded. This has become common in Australia to the point of being normal with the environment.

There can be no simple solution to the water issues given the complexity of the system and the disparate vested interests. However, this accentuates the need to identify and investigate the full range of options. Even with current knowledge some aspects of water management clearly need changing, and others need exploring. However, the necessary developments will not arise with the current approaches of attempting to resolve the problems by doing more of the same and achieving outcomes by increasing authoritarian control.

REFERENCES

References have been excluded to improve readability and promote the development of logical arguments rather than justifying comments on the views of others.

The paper was effectively completed by March 2007 but unforeseen circumstances delayed its presentation. The main consequence is limited consideration of indensation.

Most of the water use figures derive from the National Land and Water Resources Audit 2002 which is available via the Natural Resources Atlas on the Environment Australia web site. Crop productivity figures are given in the NLWRA but they derive from the Australian Bureau of Statistics

More detail on green water in provided in papers on the ERIC web site (www.eric.com.au). The most relevant papers are:

- A Soil Structural Degradation Model for Dryland Salinity
- Possibilities for Increasing and Measuring Soil Carbon
- Calculating the Effect of Organic Matter on Soil Water, Nutrient and Carbon Storage

- Global Implications of Soil Organic Matter
- Issues Concerning Mechanisms for Global Warming
- Implications of Indensation for Agriculture
- Overt Indensation by Plants
- Storage of Indensed Water in Soils
- Evolutionary Direction II

Relevant power points that should shortly be available include:

- Water Use, Recycling & Allocation
- Landscape Hydration
- Soil Degradation & Remediation
- Soil Condition & Stream Flows

ERIC