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Conflicts Between In-stream and Off-stream Uses of Rivers

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SUMMARY The conflict between in-stream and off-stream uses of rivers is explored using as an example the effect of abstraction of water from the Murray River for irrigation on the river red gum ecosystem of the Hattah-Kulkyne National Park and the Murray-Kulkyne Park. A procedure for dealing with such conflicts is put forward.

1 INTRODUCTION

This paper explores the question of the conflicts between the in-stream and off-stream uses of river water, and the policies that governments might adopt to try to deal with such conflicts.[1] This area of conflict has been largely ignored in Australia because of the emphasis on the development of water for irrigation and other off-stream uses, and the recent survey of water resources, "Water 2000", commissioned by the Department of Resources and Energy, was the first such survey in Australia to have included a systematic study of in-stream uses (O'Brien, McGregor & Crawshaw, 1983). Some attempts have been made to grapple with these conflicts in various other countries, for example the Wild and Scenic Rivers Policy of New Zealand (New Zealand National Water and Soil Conservation Organization, 1982) and the notion of Environmental Flows in the U.S.A. (see for example Utah State University, 1976), but the problem clearly needs much more attention.

To explore this problem we are taking here as a particular case study the use of the waters of the Murray River and its two major tributaries, the Darling and Murrumbidgee, which comprise the only permanent river system in inland Australia, but which between them drain over a million square kilometres, or 14% of the total area of the Australian continent (Figure 1).

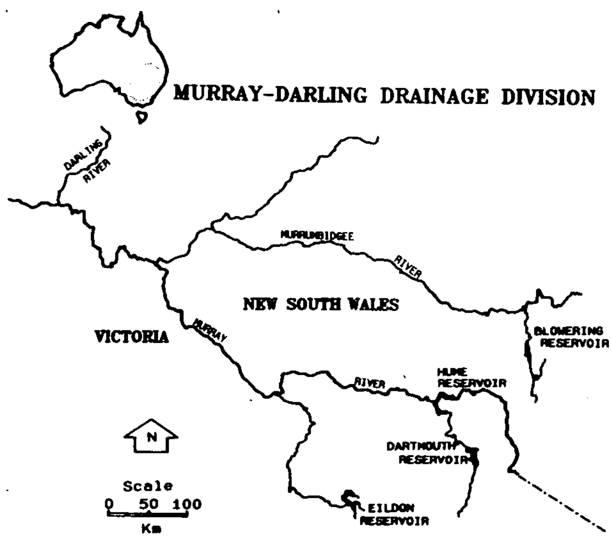

Figure 1 The Murray River system

As Australia falls largely within the high-pressure region generally known as the arid tropics (latitude 15^o - 35^o), in which evaporation rates are high and rainfall is low, the mean annual runoff of Australia as a whole is only 57 mm per year, by far the lowest of all the continents (Brown, 1983). The only appreciable rainfall within the 15 - 35^o latitude band is that precipitated from moist winds blowing off the sea and being forced to rise to colder altitudes by the Great Dividing Range, the spine of mountains extending from north to south along the entire eastern coast. Many relatively short coastal rivers fed by this rain flow individually into the sea, but the rivers flowing on the inland side of this range are all collected by the Darling in Queensland and New South Wales, the Murrumbidgee in New South Wales, and the Murray in New South Wales and Victoria. The Murray itself, over the greater part of its length, forms the border between New

1. Here we are following O'Brien et al. (1983) in defining in-stream uses as those in which the water is left in an undisturbed or relatively undisturbed state (preservation of natural ecosystems, fishing, navigation, recreation, etc.) and off-stream uses as those in which changes in the flow or pattern of flow might occur (irrigation, use of water for domestic or industrial purposes). Clearly these definitions do not easily cover disturbances such as generation of hydroelectricity and use of rivers as receiving bodies for urban, agricultural or industrial drainage, all of which might cause considerable disturbance to the river without removing any water. However for the present purposes we will confine our argument to the simple definitions noted above.

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South Wales and Victoria but it eventually flows into the sea in South Australia, and incidentally provides the water supply for Adelaide, the capital of that state. Most of Victoria lies south of latitude 35°, in an unstable pressure region where high pressure and low pressure regions alternate fairly regularly. Consequently its mean annual rainfall is higher than that of the more northerly states, being more than 400 mm in most of the state, although falls can be erratic. As a consequence the southern tributaries of the Murray, which drain only 1% of the total basin, provide 14% of the total water yield (Brown, 1983).

As a result of the climatological and topographic features sketched out above, the rainfall is not only low, but erratic, and streamflows are very variable. McMahon (1979) has calculated that whereas the coefficient of variation (standard deviation divided by the mean) for stream flows in North America, Europe and Asia are 0.3, 0.2 and 0.2 respectively, that in Australia is 0.7. In particular, flows in the Murray-Darling system are among the most unreliable in the world (Lake, 1967a). For example the maximum and minimum annual discharges of the Murrumbidgee River over the years 1907 - 1983 were 350% and 17% respectively of the mean annual discharge over that period. Flooding (i.e. overbank discharge on to the floodplain) is therefore a natural occurrence in the Murray-Darling system. Annual peaks in the Murray occur during winter and spring, with floods occurring in about four out of every five years (Helman and Estella, 1983).

The flora and fauna of inland Australia, including the riverine flora and fauna, have therefore adapted over many millions of years to dry conditions punctuated by frequent floods, and in many cases have developed reproductive cycles triggered by floods or by seasonal changes of water level in the rivers or the surrounding wetlands (Cadwallader, 1978; Frith, 1959; Lake, 1967b; Victorian State Working Group on River Murray Water and Forest Management, 1984). The wetting/drying cycle also helps to release the nutrients required to support the development and growth of these flora and fauna (Briggs and Maher, 1983).

Because of the arid conditions and variable streamflow, larger storages are required than in other countries if water is to be used for off-stream purposes. McMahon (1975) has calculated that, to achieve the same degree of utilization of water, 5 times more storage capacity is required than for rivers of the same stream flow in North America, and 11 times more for rivers of the same stream flow in Europe. In particular the Murray River and its tributaries have been extensively regulated, with 104 dams currently in operation to supply water for irrigation and domestic water supply (Helman and Estella, 1983). This has had three effects: the overall flow of the river has been reduced; winter flows have been reduced and summer flows increased because of releases of water for irrigation; and flows have been evened out from year to year, which has reduced flooding to some extent, as will be discussed later (Walker, 1979).

All of these can be expected to interfere with the natural functioning of the ecosystems of which the river is a part. Maintenance of these ecosystems is not only a very important in-stream use in its own right, but also has important influences on other in-stream uses such as fishing and passive recreation. Thus we have a conflict between the in-stream use of the river water for ecosystem maintenance (and all that goes with it) and the off-stream use of the same water for irrigation.

It would not be possible in one paper to consider the effects that impounding, release and abstraction of water for irrigation have on all the river ecosystems. As our intention in this paper is to do no more than explore the present status of the conflict and to make some observations from this exploration about future management policies, we will confine our attention to one of the most important of these ecosystems, that associated with forests of the river red gum (*Eucalyptus camaldulensis*) which occur extensively in the wetlands and billabongs associated with the river and its tributaries and anabranches.

2 THE RIVER RED GUM ECOSYSTEM

Extensive river red gum forests exist on the Murray and its tributaries but in few other places (Figure 2). The red gum is an important tree commercially (its timber is very dense and highly resistant to rotting) and the forests form a highly significant ecosystem, supporting a rich sub-culture of birds and animals, together with many other species of flora, especially black box (*Eucalyptus largiflorens*). In addition, the forests are an essential element of the landscape character of the Murray valley and are therefore very important in terms of the recreational experiences of visitors to the area.

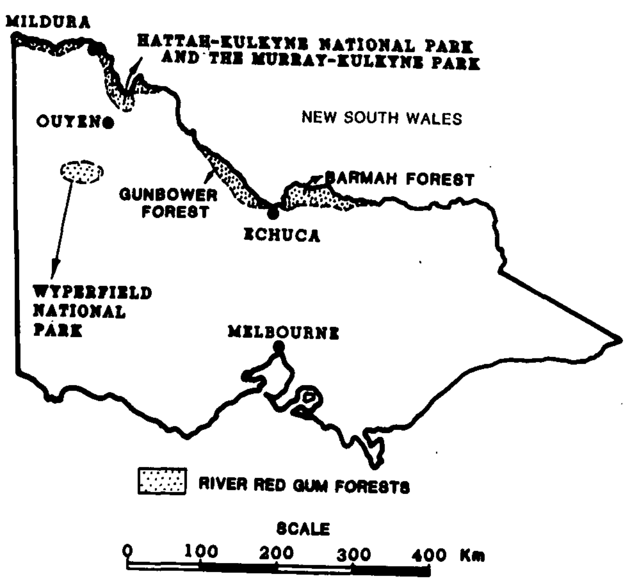

Figure 2 Major River Red Gum forests in Victoria

The river red gum has a close association with flooding. According to Dexter (1978) regeneration of a red gum forest requires that a substantial part of it be flooded at least once every two years, and this flooding must occur in the winter/spring season, as peak dissemination of the seed occurs in spring (Victorian State Working Group on River Murray Water and Forest Management, 1984). Germination of seed is prolific following recession of the flood. The duration and depth of the flooding in the season following germination are also of concern. Young seedlings not well established will die if there is insufficient water; for example seedlings which germinate after a minor inflow one year will die if there is not another inflow in the next year. Seedlings will also die if they are flooded for too long. Thus a major flood leads to prolific germination, but if there is another major flood in the following year many seedlings die (Dexter, 1970).

Flooding is also necessary to sustain tree growth in these areas of low rainfall. According to Dexter (1986), in years in which trees are not flooded there is a curtailment of growth in mature red gums, manifested in crown thinning and an increase in the amount of leaf litter dropped. In these conditions trees are also susceptible to attack by insect pests and diseases. From this we see the importance of the right quantities of water at the right times not only in the three stages of regeneration of red gums (germination of seed, establishment of seedlings, and growth of established trees), but also in the maintenance of the health of mature trees.

In addition, unseasonal floods such as those due to summer irrigation releases tend to damage well established trees, and in extreme cases may kill them (Dexter, 1978). Indeed many thousands of trees have been killed by being more or less permanently inundated in the water built up behind irrigation impoundments (Jensen, 1982). The forests are also under pressure from grazing, which restricts regeneration (Loder & Bayly, 1976).

Alteration of the flooding frequency (i.e. the number of floods occurring in a period, divided by the number of years) is known to greatly affect red gums. For example the amount of regeneration and growth are known to have decreased as a result of the reduction in flooding frequency in the Central Murray region caused by river regulation (Dexter, 1978 & 1986). The red gums in the Barmah Forest are the best known example of deterioration as a result of river regulation. In the period before the Hume Reservoir affected the natural flow, data collected from 1886 to 1933 shows that the Barmah Forest was watered in 40 out of 48 years (flooding frequency of 0.83). This compares to only 26 times out of 43 years that the forest was watered in the period after the dam was built, from 1933 to 1986 (flooding frequency of 0.60), and this second period corresponds to an appreciable deterioration of the Forest (Dexter, 1978). The Victorian State Working Group on River Murray Water and Forest Management (1984) has concluded, from the limited information available, that reduction of flooding frequency below 0.5 is likely to result in a significant reduction in tree growth and clearly detectable environmental change. Irrecoverable damage to the forest and its associated ecosystems is stated as likely to occur if effective flooding is reduced to a frequency of 0.25.

Clearly many of the forests along the river banks are seriously threatened by the above pressures. In order to conserve a representative area of the river red gum/blackbox community the Victorian government has set aside areas of it as National Parks (see Figure 2). The Hattah Lakes National Park of 178 square kilometres was declared in 1960, and in 1980 an addition to the original park was declared to create the Hattah-Kulkyne National Park of a total of 480 square kilometres and the Murray-Kulkyne Park of 16 square kilometres, which together form the park complex shown in Figure 3 (Bardwell, 1980; Wilson, 1984; Young, 1985). In 1981 UNESCO approved the Hattah-Kulkyne National Park and the Murray-Kulkyne Park for reservation as a Biosphere Reserve.[2]

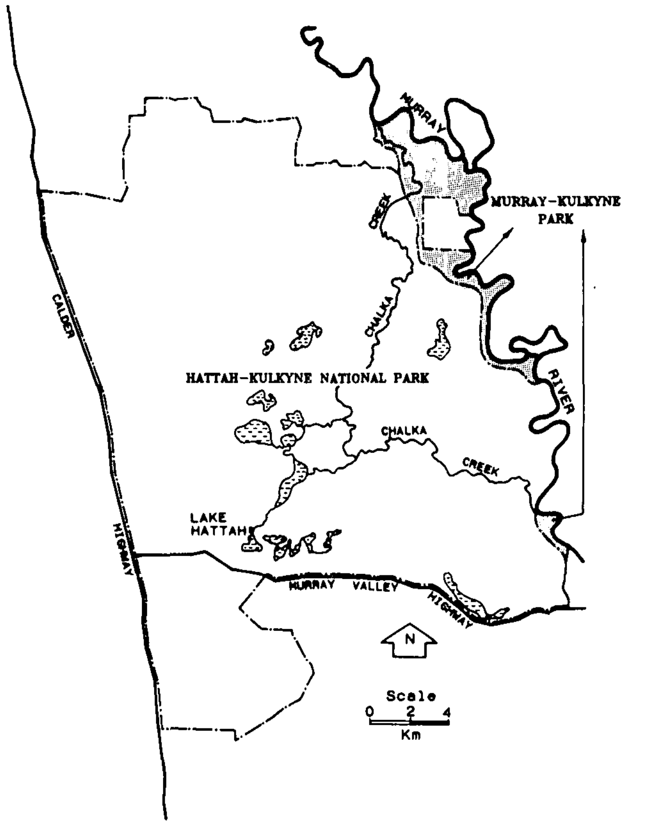

Figure 3 The Hattah-Kulkyne National Park and the Murray-Kulkyne Park

These parks contain a series of shallow lakes of various depths (hereafter called the Hattah Lakes) fed from the Murray by an anabranch called Chalka Creek (see Figure 3). When the water level in the Murray is sufficiently high, water flows into the lake system via the southern arm of the creek and also by the northern arm at a later date, filling the lakes one by one. When the river level at the entrance to Chalka Creek drops below the level needed for inflow, the water level in the lakes falls, largely because of evaporation. The larger lakes hold water for up to three years after inflow, with the shallower lakes drying up in one or two years, thus providing suitable habitat for many species of wildlife, as well as permitting germination, establishment and growth of red gums.

2. Biosphere Reserves are protected areas selected to form a network of samples of the world's major ecosystems. By 1983 there were over two hundred of these worldwide, and the one under discussion is one of the twelve in Australia (Young, 1985).

However, the declaration of these areas as parks does not necessarily ensure that the red-gum ecosystems in them will survive. As we have indicated above, this particular ecosystem is critically dependent on the frequency, extent and timing of floods, and regulation of the main river system to provide for off-stream uses must affect all of these. We turn now to an examination of the effects of regulation of the Murray system on inflows to the Hattah Lakes, and the flooding regimes in the Lakes.

3 EFFECTS OF REGULATION OF THE MURRAY RIVER ON FLOODING REGIMES IN THE HATTAH LAKES

As the Darling enters the Murray downstream of Chalka Creek it cannot contribute to flooding of the Hattah Lakes area, and we will confine our discussion to the Murray/Murrumbidgee system. Figure 1 shows the location of the principal reservoirs in this system, and Table I indicates their dates of construction, the capacities when full, and the purposes for which they were constructed. The ratio of reservoir capacity in gigalitres to mean annual flow into the reservoir in gigalitres per year gives the number of years supply which the reservoir can hold, which we have called the regulatory capacity. Table I shows that, with the exception of the Dartmouth Reservoir on the Mitta Mitta River, these reservoirs have fairly modest regulatory capacities in the range of one to two years, and that the regulatory capacity of the whole system is also less than two years.

Because of the irregularities in rainfall from year to year, the total annual flow of the river varies considerably from year to year. For example, consider flows at Euston, the nearest gauging station to Chalka Creek. 40% of the years between 1895 and 1982 had flows less than half of the mean annual flow, and 15% of the years had flows greater than twice this flow (State Rivers and Water Supply Commission of Victoria, 1984). Flooding is not likely to be appreciably affected by regulation in these years of heavy flow, (e.g. 1946, 1947, 1956, 1964, 1965, 1974), in which flows are far greater than the total volume of the reservoirs.

Streamflow variability complicates analysis of the effects of various reservoirs on flows into the lakes system, as variations in inflow frequency due to construction of the reservoirs may be overshadowed by random variations due to fluctuating weather conditions. Nevertheless a clear enough picture does seem to emerge. Table II shows the frequency of inflows[3] to the Hattah Lakes and of major spring flooding for the period before any regulation of the river occurred, and for the periods between and after construction of the major

TABLE I

PRINCIPAL RESERVOIRS IN THE MURRAY-MURRUMBIDGEE SYSTEM (BAKER AND WRIGHT, 1978)

Reservoir	River	Date of completion	Principal purpose	Gross capacity, GL	Mean annual stream flow GL/a	Regulatory capacity years
Eildon (1)	Goulburn	1927	irrigation	3400	1500	2.3
Hume (2)	Murray	1936	irrigation	3000	2200	1.4
Blowering (3)	Tumut	1968	hydro-electricity	1600	1700	.9
Dartmouth (4)	Mitta Mitta	1979	irrigation	3700	850	4.4
Total	Murray/Murrumbidgee above Euston (5)			14000	9000	1.6

Notes
(1) Strengthened and extended to full capacity in 1958.
(2) Strengthened and extended to full capacity in 1961.
(3) Built to retain water diverted under the Great Dividing Range from the Snowy River.
(4) Declared effective for purposes of the River Murray Agreement in November, 1979.
(5) Euston is the gauging station on the Murray River closest to Chalka Creek, the takeoff to the Hattah Lakes.

3. The criterion used to define an inflow here is that the level in Lake Hattah (which is equipped with a level gauge) has risen by at least 0.3 m, an occurrence which can be related to the flow in the Murray at Euston exceeding a value of about 37 GL/day for a month. As seen from Figure 3 Lake Hattah is almost the last of the lakes to be filled, and if its level has risen then all the other lakes will have filled also. The inflow criterion makes no distinction between relatively small inundatations of the Hattah wetlands which might recede in a month or so, and major inundations which could prevail for much longer periods. The criterion used in Table II to define a major flood is that the level of Lake Hattah reached 3.5m in August/September compared to its natural retention level of 2.7m. This can be correlated with the flow at Euston exceeding a value of 82 GL/day for the whole of August and September.

TABLE II

FREQUENCY OF INFLOWS TO THE HATTAH LAKES AND MASSIVE FLOODS IN THE MURRAY SYSTEM

Event	Years over which the calculation was made	Inflow frequency (c)	Flooding frequency (d)
Prior to any major regulation	1887 - 1927 (a)	.81	0.05
The effect of the Eildon and Hume Reservoirs	1930 - 1977 (a) 1931 - 1971 (b)	.48 .48	0.06 0.15
The effect of the Eildon, Hume and Dartmouth Reservoirs	1931 - 1971 (b)	.46	0.15

Notes (a) Calculated from records of flows.
(b) Calculated by using flows simulated by the River Murray Commission (1974).
(c) Calculated using the criterion of 37 GL/day for one month at Euston or Mildura.
(d) Calculated using the criterion of 82 GL/day during August and September at Euston or Mildura.

reservoirs. In the case of Dartmouth Reservoir, which was completed in 1982, we have to rely on simulations of what would have been expected to occur over the years 1931-1971 had Dartmouth Reservoir been in operation (River Murray Commission, 1974). This table shows that the frequency of major spring floods associated with massive germination episodes is unaffected by river regulation, as would be expected from the discussion in the preceding paragraph. However, the frequency of inflows to the Hattah Lakes has fallen from the preregulation figure of 0.8 inflows per year to 0.5. Some alterations were made to the mouth of Chalka Creek in 1972 in an effort to counteract the effects of regulation of the river on inflows, but the effects were minimal. In other words water used to flow into the Lakes nearly every year, but now this occurs only once in two years on average.

From the discussion of field studies of red gums in the Barmah Forest in Section 3 it is apparent that the inflow frequency in the Hattah Lakes has already dropped to the level at which significant reduction in germination, establishment of seedlings and tree growth can be expected to occur, and that any further reductions could lead to permanent damage to the forest through absence of regeneration and reduction of growth, accompanied by increased susceptability of established trees to disease and insect pests (Dexter, 1970, 1978, 1986).

4 MANAGEMENT POLICIES

The release of water from storages on the River Murray is controlled by the River Murray Commission, a statutory authority set up in 1917 following the ratification of the River Murray Waters Agreement between the Commonwealth of Australia and the States of New South Wales, Victoria and South Australia, the three states through which the Murray flows and which benefit from its water. The original Agreement laid down monthly entitlements for South Australia to provide for the city of Adelaide, stated that the states of Victoria and New South Wales were entitled to use the waters of the tributaries of the Murray flowing in their own states and laid down a basis for sharing water in the trunk of the Murray remaining after South Australia's entitlements had been met. The Agreement did not provide for any allocation of water for in-stream uses.

During the first 50 years of operation of the Commission various reservoirs and impoundments were constructed, the largest of which are shown in Table I, many irrigation schemes were instituted, and many environmental problems became manifest, largely arising from the regulation of the river leading to changes in the flow pattern and to reduction in flow, and from poor irrigation practices leading to salinization. The dissolved solids content of the river steadily rose over this period, reducing the potability of the water supplying towns along the river, especially the city of Adelaide which was at the end of the line (Morton and Cunningham, 1985).

All of this led to a rethinking of the management of the river, including a proposal to further regulate the waters with a large-capacity reservoir designed especially to make provision for drought years. Analysis of many proposals led to the adoption of the proposal for the Dartmouth Reservoir on the Mitta Mitta River, as shown in Figure 1. A new Agreement was reached in 1982 (see for example Victoria, 1982) to take into account the extra flexibility created by this reservoir, and for the first time some water quality objectives were included in the Agreement to guide the Commission in the management of the whole system. The Agreement also gave the Commission some powers over the operation of reservoirs in tributaries in the states of Victoria and New South Wales, thus recognizing that the whole interconnected river system had to be operated as a system if any overall objectives were to be met (Clark, 1982).

Let us now turn to the management of National Parks. The National Parks Act (Victoria 1975) states its objectives very clearly. Schedule 2 of the Act (which covers the larger Hattah-Kulkyne National Park) states that the Director of the National Parks Service shall:

"i. preserve and protect the park in its natural condition for the use, enjoyment and education of the public,

ii. preserve and protect indigenous flora and fauna in the park."

Similar provisions are made for parks such as the Murray-Kulkyne Park which are not designated as National Parks. Schedule 3 of the Act, which covers these parks, requires the Director to "preserve, protect and re-establish indigenous flora and fauna in the park".

From what has been said earlier it should be clear that these objectives are unlikely to be met on a long-term basis in the Murray-Kulkyne Park and Hattah-Kulkyne National Park unless inflows to the Lakes are managed in such a way as to maintain an adequate flooding frequency. The River Murray Agreement of 1982 makes no mention of any allocation of water for any environmental purpose, although the maintenance of the flows required to give Adelaide its entitlement does ensure that the flow in the main trunk of the river does not fall below a minimum value at any time. It should be noted, however, that these minimum flows are only about one tenth of those necessary to cause a flow into Chalka Creek with consequent filling of the Hattah Lakes. Moreover the 1982 Agreement, even though it does at last recognize the importance of water quality, does not recognize as an objective the management of the river in such a way as to provide for in-stream uses.

Thus we have the situation where the Director of the National Parks Service might consider that to carry out his duties would require on occasions that the Hattah Lakes be artificially flooded in the winter/spring season, for example after several years in a row without inflows. This in turn would require the level of some water in the Murray to be raised by release of water from the reservoirs, instead of saving it for later release for irrigation purposes. However the River Murray Agreement does not permit the River Murray Commission to take account of such considerations in determining whether water will be stored or released at any time, and the Director of the National Parks Service would have to do without.

To achieve the desirable situation of the long-term maintenance of these parks the following changes would be needed:

i. Alteration of the River Murray Agreement to include as one of its general management objectives the maintenance of in-stream uses of the water, with particularly significant in-stream uses in specific reaches of the river being individually named (maintenance of the ecosystems of the Hattah-Kulkyne National Park and the Murray-Kulkyne Park would be one such specific use),

ii. Rewriting of the legislation underpinning the River Murray Agreement to permit the reserving of water for these uses, and the management of the water resources to serve them.

iii. Long-term monitoring of the state of various ecosystems, and analysis of the use of the river for various in-steam uses, to determine what management practices are required to maintain and enhance these uses,

It is recognized here that the program of research, legislation and management suggested above implies that in-stream uses are to be seen to be more important in the eyes of the community, and hence to the government decision-makers, than they are at present. The National Parks Act does recognize this importance in theory, and it would be hypocritical of the community and the government serving it if this recognition were not followed up by appropriate action.

Although our argument has centred around one particular in-stream use in one particular river system, similar situations exist with respect to desirable in-stream uses in virtually every river system in the world, and we believe that this is a problem which should receive more attention. The three steps sketched out above are the same three steps which should be undertaken in all such cases if the particular in-stream use is desired to be maintained. However, it is recognised that not all in-stream uses will be able to be maintained, since this can only be done at the expense of off-stream uses. Trade-offs between on-stream and off-stream uses of water will have to be made in many cases. However, the first step which should be taken in all cases is the recognition that in-stream uses of rivers have an inherent importance which warrants them as being as worthy of consideration as off-stream uses.

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