FRESHWATER SYSTEMS, CONFLICT MANAGEMENT AND ECONOMIC SECURITY

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11 May 1999

A framework paper prepared for presentation at an IUCN Workshop of the World Water Council, Bangkok, June, 1999. The authors would like to thank David Pearce and Ger Bergkamp for their assistance in the undertaking of this project. Comments please to Professor Timothy Swanson, Department of Economics and CSERGE, University College London, Gower Street, London WC1E 6BT, Tim.Swanson@ucl.ac.uk

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1. Introduction

A freshwater system interlinks all of the various users within the economic and natural systems dependent upon it. Freshwater resources are key to the survival of both systems, providing a flow of essential services to both. This paper strives first to identify and understand the linkages between freshwater ecosystems and economic systems, and then to postulate how humankind could improve management structures so as to manage the myriad of human and natural linkages which are embedded within this system. Thus section 2 of the paper defines freshwater ecosystems in terms of their economic functions, and defines economic systems in terms of their impacts (both positive and negative) on freshwater ecosystems. Section 3 outlines the general nature of the problem that the vision must address. Section 4 provides a more detailed depiction of the problem of freshwater resource management. Section 5 then proposes some strategies for addressing the problem given the various constraints and perspectives of the scenarios. Section 6 concludes with a number of points intended to stimulate discussions at the workshop in June.

2. Freshwater ecosystems in economic terms and economic systems in freshwater terms - interlinkages

2.1 Freshwater ecosystems in economic terms

2.1.1 The goods and services provided by freshwater ecosystems with associated values

According to Barbier, Acreman and Knowler (1997) wetlands are among the Earth’s most productive ecosystems. Freshwater ecosystems provide a number of goods and services to economies locally, nationally, regionally and globally. The agriculture, tourism, fisheries, forestry and construction industries (to name but a few) all benefit both directly and indirectly from wetlands. Goods derived from freshwater ecosystems include fish, timber and fuel, wildlife, fertile land and, of course, water. These, along with services such as transport, recreation and scientific study are examples of
direct uses of freshwater ecosystems. Indirect uses include storm protection, sediment and pollution retention, nutrient retention, evaporation and preservation (in archaeological terms). Through these goods and services freshwater ecosystems provide people with a string of benefits which are valued at local, national, regional and global levels. In addition to the benefits and related values associated with the goods and services, people also intrinsically value freshwater ecosystems. This intrinsic value is linked to the aesthetic, cultural and heritage significance of a freshwater ecosystem. For instance, many value Victoria Falls in southern Africa regardless of whether they will ever visit, view or in any way ‘use’ the falls. In short, as summarised in Figure 1, freshwater ecosystems generate multiple and wide-ranging economic benefits, on and off-site.

2.1.2 Private goods and public goods: complex linkages between users
The array of goods and services provided by freshwater ecosystems can be conceived of as falling within or between two groups of goods: public and private. Whether a good is essentially public or private is used to determine how best it can be managed, and thus the institutional structures needed to manage freshwater ecosystems. It is important to recognise that most of the goods and services emanating from freshwater ecosystems are themselves very complex. They represent complex forms of interaction between existing and potential users, and these complex interactions require equally complex forms of intervention and management.
Public goods are goods and services whose provision is “non-excludable” and “non-divisible”. This means that once they are provided, anyone can benefit from their provision without subtracting from their availability to others. A classic example of an environmental public good is the water purification service of a freshwater ecosystem. If an ecosystem is maintained adequately to provide water purification services, these services would be available to all down-stream consumers of that water supply without subtracting from the available purity. Many of the quality-related facets of the goods and services flowing from a freshwater ecosystem may be conceived of as public goods. These include water quality, storage and purification, groundwater recharge, flood control, storm protection, nutrient retention, micro climate and shore stabilisation. If managed properly for one user, such goods are managed properly for all users. Conversely, when they are poorly managed, all suffer from this poor management. In effect, these are goods and services where the users remain inter-linked in complex relationships, by virtue of the complexity of the flows of the freshwater ecosystem from which they all benefit.

Private goods, on the other hand, are goods and services whose provision is “excludable” and “divisible”. Once these are provided to someone, they are held exclusively by that individual and their disposal subtracts from the total supply available to others. These sorts of goods and services are simple and discrete. The linkages between users in these contexts may be readily reduced to simple, market-based transactions. Many of the quantity-related facets of the flows of goods and services from freshwater ecosystems are of this nature. For example, once a quantity of water has been appropriated for use or consumption, it is usually viewed as the exclusive property of those individuals controlling it.

The public or private nature of a freshwater ecosystem's goods and services will help to determine how it can most efficiently be managed. Market-based processes are best suited to managing private good aspects of freshwater ecosystems because markets provide economic incentives to individual decision makers. Examples include water sales in western Canada and the United States, fish markets in Southeast Asia, and fuelwood or peat sales in Africa or South America. Often, however, the market signals are garbled by non-market institutional structures such as property rights, access rights, and so on. Thus with respect to creating the right incentives for conservation and sustainable use, these institutional structures need to be designed to ensure that individuals are getting the right set of signals to invest in the private good aspects of freshwater ecosystems. This point will be revisited throughout the paper.
More importantly, the prevalence of public good aspects in freshwater flows implies more complicated forms of public sector involvement in freshwater ecosystem management. By virtue of their nature, the public good aspects of freshwater systems are likely to receive less-than-adequate private attention both in terms of management and financing. Thus private sector measures will need to be complemented by public sector measures in order to ensure the provision of public good aspects of freshwater ecosystems. The complexity of public intervention required to ensure the conservation of these more complex functions is a fundamental problem in their management. Balancing public and private measures in the management of freshwater ecosystems is a core subject of this paper.

In either case, the important message is that the flows of goods and services from freshwater ecosystems are not, in general, simple, discrete and easily commoditised forms of goods and services. They are instead complicated flows, and they present a complex matrix of interactions between the various users of the freshwater ecosystem. The fundamental message of this paper is that the form of intervention that is required is a complicated one, on account of the complexity of the interactions that it must manage.

2.2 Economic systems and impacts on freshwater ecosystems

2.2.1 The quantity of freshwater and the impacts of economic systems
Clearly freshwater ecosystems and the related goods they provide are essential to both environmental and socio-economic systems. One key good provided by freshwater ecosystems is water. Water is important to humans for direct consumption, for irrigation, for livestock and for industrial use (to name but a few uses). Water is also important to sustain all other species (biodiversity) for both direct consumption and for suitable habitat. As the human population of the world grows, its demand for water increases. And this expanded appropriation by humans may mean a contracted supply for biodiversity. Additionally, the withdrawal of water from freshwater ecosystems can render those ecosystems unable to provide many of the goods and services described in 2.1.1. In short, the continuing expansion of human demand for the goods and services from freshwater ecosystems creates conflicts between human needs and the requirements of other, natural demands on freshwater services.

There are, of course, many societal conflicts over freshwater resources as well. Nevertheless, if today’s runoff of water was evenly distributed across the world and easily accessible to all, then each year more than 8,000 m$^3$ of water would be available to every person on earth. A society is not considered to be under ‘water stress’ until the renewable supply per annum is less than 2,000 m$^3$. Thus, globally there appears to be sufficient
freshwater for human needs (Falkenmark and Lindh, 1993). But, of course, freshwater resources are not distributed evenly across the world nor are they accessible to all. Its distribution varies over place and time. Table 1 shows the per capita difference in available freshwater between continents.

<table>
<thead>
<tr>
<th>Region</th>
<th>Annual internal renewable water resources m$^3$/yr per capita 1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>7690</td>
</tr>
<tr>
<td>Oceania</td>
<td>75,960</td>
</tr>
<tr>
<td>North and Central America</td>
<td>16,260</td>
</tr>
<tr>
<td>USSR</td>
<td>15,220</td>
</tr>
<tr>
<td>Africa</td>
<td>6,460</td>
</tr>
<tr>
<td>Europe</td>
<td>4,660</td>
</tr>
<tr>
<td>Asia</td>
<td>3,370</td>
</tr>
</tbody>
</table>

Source: Gleick, 1993: 129-133.

Large variations also exist at the national, regional and local levels as well. For instance, while the continent of Africa has annual renewable freshwater resource of 6,460 m$^3$/yr per capita, 30% of total runoff in Africa comes from the Congo river basin. At the national level Somalia has only 1520 m$^3$ renewable freshwater resources per capita per year. In South America, while Chile obtains 35,530 m$^3$/yr per capita, the city of Arica commonly records zero annual rainfall (Gleick, 1993). These spatial variations are compounded by seasonal variations in rainfall and hours of sunlight. In India, for example, a majority of the rain comes during the few weeks of the monsoon. Thus at the national, regional and local levels, societies experience water stress. (Such natural variation can help to maintain biodiversity in terms of richness in ecosystems, species and genes, but these variations can create pressures for human societies. The resulting reactions of these societies can have very serious negative economic and ecological impacts.)

2.2.2 The quality of freshwater and the impacts of economic systems

Economic activities also impact on freshwater ecosystems in the form of pollution which further reduces the amount of freshwater available both for humans and natural systems. “Polluted water is responsible not only for 80% of all illnesses but also for massive disturbances of aquatic ecosystems” (Falkenmark and Lindh, 1993: 81). On the other hand, clean freshwater is an important resource for human and natural systems. Thus it is the quality of freshwater – its freshness – that determines its usefulness to both nature and society.

Many human uses of freshwater affect the quality of the freshwater system, which in turn affects the types of goods and services the freshwater
ecosystem can provide. Thus economic uses of freshwater resources must be analysed for the impacts on the quantity of freshwater available for other uses as well as for the impacts on the quality of the remaining ecosystem.

**Figure 2 The Relationship between the Ecosystem and the Economic System**

The figure above demonstrates that the amount of freshwater available for natural and economic systems depends on both its *quality* (a function of the quantity of waste it contains - $q_w$) and its *quantity* (a function of the amount of water extracted - $q_n$). Freshwater is representative of water with low levels of concentrations of other contaminants. As more water is extracted, the concentration of waste to water will increase and so the quality will decrease.

Thus societal conflicts over freshwater resources involve both the conflicts between users for freshwater services, and the conflicts between waste producers and water users. The exact nature and location of pollutant significantly affects its ultimate concentration within the freshwater system, and thus its effects on human health and the environment. The quality necessary for different uses varies and thus so does the effect of pollution on availability. Drinking water requires a higher quality than industrial or recreational use, and thus the availability of drinking water will be affected by even lower concentrations of pollution (Nash, 1993). Access to safe drinking water is shown in Table 2 for developing countries; the data emphasises the disparity between water availability at the regional and local levels.

| Table 2 Water supply coverage for developing regions 1980 and 1990 (%) |
|---------------------|-----------------|-----------------|-----------------|-----------------|
| Africa              | 83              | 87              | 33            | 42            |
| Latin America and the Caribbean | 82              | 87              | 47            | 62            |
| Asia and the Pacific | 73              | 77              | 28            | 67            |
| Middle East         | 95              | 100             | 51            | 56            |
| Total these regions | 77              | 82              | 30            | 63            |

Source: Gleick, 1993: 188.
2.3 Conclusion – Interlinkages within the Systems

The linkage between natural and economic systems is determined by the hydrological system. The system of evaporation, precipitation, filtration, and again evaporation links freshwater ecosystems around the world. Users have impacts on other uses and users via these linked impacts across the system. Thus a change in the quality of freshwater resources in one place affects a change in the quality of the freshwater in another part of the ecosystem. In this way those using the freshwater are linked to one-another and the economic concept of externalities is particularly important for understanding the impact of economic systems on freshwater ecosystems. We not turn to the examination of the problem of such interlinkages in section 3.

3. The General Problem

Once we recognise that freshwater ecosystems provide a number of goods that are valued by individuals in society and that an individual’s consumption of these goods impacts the freshwater ecosystem, we are then able to model the interactions between uses. Consider an individual’s utility function that is dependent upon both the goods and services received directly from the freshwater system and a set of economic activities that indirectly make use of that system.

\[ U_A = U (X_1, X_2, ..., X_n; Q_1, Q_2, ..., Q_m) \]

Where \( U_A \) is an individual’s utility of the freshwater ecosystem, \((X_1, X_2, ..., X_n)\) are the individual’s economic activities which impact on the freshwater ecosystem and \((Q_1, Q_2, ..., Q_m)\) are the goods and services provided directly to the individual by the freshwater ecosystem. The individual’s utility is therefore a function of both his or her economic activity and of the goods he or she derives from the freshwater ecosystem. The freshwater ecosystem supplies utility to the individual directly via the vector of goods and services \((Q)\) and indirectly via the impact of economic activities \((X)\).

Interaction is represented by the relationships between direct and indirect flows. An increase in economic activity \((X_1, X_2, ..., X_n)\) may decrease the quality or quantity of the freshwater goods \((Q_1, Q_2, ..., Q_m)\). For example, suppose \(X_1\) is representative of the magnitude of agricultural production (e.g. sugar cane which is often produced in heavily irrigated fields) that may result in the reduction of wetland habitat services within the freshwater ecosystem, say \(Q_1\). An increase in the economic activity increases the individual’s utility, i.e.

\[ \frac{\delta U_A}{\delta X_1} > 0. \]
but there is an implicit decline in the flow of direct services from the ecosystem by reason of the increase in agricultural activity, i.e.

\[
\frac{\delta Q_1}{\delta X_1} < 0.
\]

This decrease in the flow of direct services from the ecosystem reduces the utility of the individual by the amount of

\[
\frac{\delta U^A}{\delta Q_1} \cdot \frac{\delta Q_1}{\delta X_1} < 0.
\]

The net effect is ambiguous depending on the relative strengths of the direct and indirect effects of this expansion in economic activity. It is important to recognise that, irrespective of the magnitude of this effect, it clearly would be internalised, i.e. both the direct and the indirect effects of the increased economic activity are flowing to the same individual.

An *externality* is the effect of producing or consuming a good whose impact on third parties is not reflected in the price of the good. An externality can be either positive or negative. Uses of freshwater ecosystems which may have negative externalities could include actual water consumption, if the water has no price and is then made unavailable to downstream users (this is a 'consumption-related' externality). A 'production-related' externality related to freshwater ecosystems may be the impact of pesticides applied to farmland in a watershed that then renders the downstream water unsuitable for either natural or economic systems.

This effect would constitute a *negative externality* if the economic activity was undertaken by one individual while the reduction in the flow of ecosystem goods and services accrued to another.

*Negative Externality* (for increased economic activity $X_1$)

\[
\frac{\delta U_B}{\delta Q_1} \cdot \frac{\delta Q_1}{\delta X_1} < 0
\]

\[
\frac{\delta U_A}{\delta X_1} > 0
\]

It is clear from this example that the use of freshwater ecosystems for one purpose will often reduce the available flows of goods and services for other users or purposes. In short there are many conflicting demands placed on the total flow of goods and services available from a freshwater ecosystem. The resulting scarcity of freshwater ecosystems is then a ‘relative scarcity’ – it is scarcity induced by means of unmanaged interactions. This is the sort of
problem which may, in principle, be addressed through a correct set of prices (Hanley, Shogren and White 1997). Such prices would reflect the costs inflicted upon others by reason of the use or appropriation of some of system’s flow of services. A theoretically correct set of prices would channel the available flows to the first-best uses in accordance with the values that those uses generate. However, pricing some of the values generated by freshwater ecosystems may be extremely difficult if not impossible. This is in part due to an array of market and government failures. It is usually the case that the array of interactions from a single activity impacting upon an ecosystem is just too complex to afford the option of a simple form of intervention, market-based or governmental.

3.1 Market failure

Markets are institutions that organise economic activity through prices which communicate the values within and the constraints upon a society. The decentralised decision-making processes of the market – where every individual is able and responsible for making his or her own choices is the very strength of the market. Optimal private decisions based on mutually advantageous exchange lead to optimal social outcomes. But for freshwater goods and services, markets can fail if prices do not accurately reflect society’s desires and constraints. (Hanley, Shogren and White 1997) This can happen if the benefits related to the freshwater ecosystem’s public goods are not reflected in the prices.

3.1.1 Externalities

When a party does not take into account the effects of its water use on others, then the private and social marginal cost curves will diverge. This is shown in Figure 3. For instance when an individual A in the example above
considers whether or not to undertake an additional unit of agricultural activity, it will not necessarily consider the impact of this expansion on the other users of the ecosystem, such as B in that example. As a result, the individual acting independently tends to use the water to a greater extent than is “socially optimal” (i.e. optimal from the joint perspective of A and B). This is represented in Figure 3 by the depiction of Individual A’s decision making inclusive of its impacts on B (Marginal Social Costs) and exclusive of those impacts (Marginal Private Costs). The individual acting noncooperatively will end up consuming water services at Q\(\text{nc}^0\) rather than Q\(^*\), the socially optimal equilibrium level of consumption.

This excess use of the water resources imposes an external cost on society that is not paid for by the user. That is, one way to think of this externality is as a market failure, where Individual A is not paying the full opportunity costs of the water it is exploiting. The under-pricing of the water resource results in its excessive exploitation in the activity chosen by A, a social inefficiency.

In other words, social inefficiencies through resource misallocation may be conceived as the failure to place resources into their first-best uses. When an individual is able to appropriate the use of a resource without considering the opportunities others would have by use of that resource, then the resource will be misallocated toward that individual’s activities. From the societal perspective, more beneficial use from the resource would be achieved if it were allocated to its best uses first.

Since it would be socially optimal to reduce consumption by A from Q\(\text{nc}^0\) to Q\(^*\), it should be in the interests of all parties concerned to co-operate and reallocate the resource. In effect, if resources are priced in some manner, then they should be able to be reallocated toward their first best uses, by means of private transactions within the market. This is one of the implications of the so-called Coase Theorem.

However, in many cases concerning water resources, many kinds of users with heterogeneous uses located across management boundaries presents a complex set of interactions that make it difficult to conduct transactions regarding the resource. These differences and difficulties are causes of transactions costs, and such costs are the reasons that markets fail to achieve optimal resource allocations.

Contracts for cooperation in resource allocation become increasingly complicated to achieve when multiple actors are involved. One reason is that there is the need for incentives to reallocate resources, and these become complicated with large numbers. First, while society as a whole is
better off if water consumption is reallocated, it is necessarily the case that some individual users will be made worse off. These actors have an incentive firstly not to co-operate at all in attempts to reach a social optimum, preferring to free-ride on the activities of others. If some players agree to decrease their consumption levels, they will be able to free ride on this cooperation in order to have access to more water at no private cost. Secondly, this implies that there will be a need to agree some distribution of benefits, or payoffs, that will achieve the cooperation of all users. This is the fundamentally difficult task of agreeing resource reallocation – the *bargaining problem* over resource allocations.

The asymmetric benefits of co-operation cause one of the biggest barriers to reaching a socially-preferred agreement. In order to ensure that apparent losers will sign, it is necessary to agree on the way in which the gains from an agreement will be distributed. The bargaining problem is illustrated in Figure 4. The range of possible outcomes is the entire area on and under the curve in that diagram – the bargaining frontier. The curved bargaining frontier contains all possible optimal welfare outcomes from bargaining, comprising different combinations of utility to players one and two. The combined welfare of the parties is maximised at any point on the bargaining frontier.

![Bargaining Frontier Diagram](http://economics.iucn.org)

**Figure 4 Potential Gains from co-operation**

The point × represents a non-cooperative equilibrium, such as Q\(^{nc}\) in Figure 3. As it is well within the bargaining frontier, it provides a much lower level of combined utility than could be reached. The difference between × and the bargaining frontier represents the potential gains from cooperation to individuals A and B.
As outlined above, neither player would sign an agreement if they felt it made them worse off. Thus party 1 would not be prepared to accept a level of welfare lower than a, while player 2 would not accept a level of welfare lower than b. The arc ab represents the range of agreements that maximise joint welfare and improve or at least maintains, the level of welfare of each player.

Only through co-operation and agreement on the distribution of gains from water management will the frontier be reached and the exact location on ab be determined. This is the essence of the bargaining problem: a cooperative gain can be achieved only after the allocation of the shares of that gain have been agreed.

Given the institutional and stakeholder complexity regarding users of freshwater ecosystems, however, market forces are quite likely to fail to bring about a move to the arc ab. As explained in Box 1, a system of market-based side payments may not be so easy to establish.

### Box 1 Side Payments

Side payments allow parties to an agreement to redress the cost burden between signatories. By fully compensating signatories for any losses, they can encourage parties to sign where their inclusion in agreement is essential if the treaty or organisation is to be credible and sustainable. For instance, in the pollution of a river, there would be no private benefit to 9 out of 10 polluters reducing pollution levels by mutual agreement if the 10th outside the agreement continues to pollute and thus the quality of water remains too low.

However, the intricacies of the interactions between parties in the case of water mean that the magnitude and direction of side payments will be difficult to determine precisely. At the regional level, politicians would have to decide which social groups were most deserving, and moreover which had the most political influence. At the national level, the varying development status and size of nations would make an allocation of payments hard to determine. ‘Cash transfers may be too explicit a payoff to be politically acceptable within the existing political environment, so other forms of exchange or factorable assignment of property rights must be devised’ (Libecap, 1989: 23)


### 3.2 Government failure

An alternative to market-based solutions is government regulation and management. But with respect to freshwater ecosystems, governments too have their failings. In essence, the same complexities that render market
transactions difficult in this context are also present to render governmental solutions difficult.

3.2.1 Boundaries
One major challenge for regulating the goods derived from freshwater ecosystems is the issue of boundaries. If freshwater ecosystems adhered to delineated zones, defining management responsibilities and access rights would be a straightforward question. Farmers could simply be allowed to use water extracted from their land, countries could use whatever water flowed inside their national boundaries, and so on. A single regulatory institution could manage the freshwater ecosystem to maximise the welfare of its users.

In reality, however, freshwater ecosystems span many political and bureaucratic boundaries. It is rare that a single management institution has responsibility for a whole ecosystem. Furthermore, responsibility for the diverse range of goods the freshwater ecosystems provide are spread across a multitude of private and public sectors. Box 2 describes some types of boundaries and outlines how freshwater ecosystems cross them.

Box 2: Incompatibility between Freshwater System and existing Management Institutions

Water resources cross constructed management boundaries at every level.

1. Land Boundaries
   At the local level, water sources cross land boundaries; rivers are shared by neighbours, groundwater aquifers lie under more than one farm. As a result users and uses interact; e.g., the disposal of waste in a river by one user will affect the quantity of clean water available to their neighbour. Irrigation will affect the flow of water available downstream.

2. Local Government Boundaries
   At the local government level, several states may depend on the same aquifer, so that, as in the Edwards Aquifer, Arizona, pumping by the population of one state affects the water available to users across the state boundary (Anderson, 1997).

3. National Boundaries
   At the international level different countries often rely on the same water resource. There are over two hundred international river basins. A river such as the Niger which is approximately 4,160 km long flows through 10 countries (Gleick, 1993: 151) and in Asia 65% of the total land area is encompassed by an international river basin (Gleick, 1993:436). As a consequence the water using activities of nations are interconnected.

It is hard for this array of entities to identify let along monitor impacts on other users of the uses they manage. So long as each management entity acts independently it only has an incentive to maximise the welfare of its own members. Similarly, these institutions may be unaware of the activities of
other users of the ecosystem. This may be especially true for their impacts on many of the less noticeable public good functions of such systems, such as the support of biodiversity. Given that these public good functions are spread across many governmental units, the incentive to manage for it is dissipated across these units. In the absence of providing for these functions, the management institutions are unable to take into account the full costs and benefits of their users’ actions and therefore are unable to identify the most efficient allocation of the goods and services of the freshwater ecosystem. In short, a multitude of management institutions replicates at the governmental level the problem of coordination and cooperation that exists with multiple users in the private sphere.

3.2.2 Heterogeneity in Users and Uses
The parties associated with the various management entities are likely to differ. Farmers associated with the Ministry of Agriculture will have different uses of the freshwater ecosystem than hotel owners associated with the Ministry of Tourism or urban residents whose interests may be represented by a local Water Bureau.

Even within these groups there is heterogeneity in the uses. Industry will use freshwater ecosystems both for production (quantity) and for dumping waste (quality). Individuals sharing the same water resource may require it for drinking and recreation. This diversity is outlined in Table 3.

<table>
<thead>
<tr>
<th>User</th>
<th>Quantity-related uses</th>
<th>Quality-related uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreational</td>
<td>Boating, Swimming</td>
<td>Oil, General</td>
</tr>
<tr>
<td>Domestic</td>
<td>Drinking, Washing</td>
<td>Sewage</td>
</tr>
<tr>
<td>Agricultural</td>
<td>Irrigation</td>
<td>Pesticides, Fertilisers</td>
</tr>
<tr>
<td>Industrial</td>
<td>Consumption, energy</td>
<td>Chemicals</td>
</tr>
<tr>
<td>Forestry</td>
<td>Trees</td>
<td>Soil, Silt</td>
</tr>
<tr>
<td>Fishing</td>
<td>Fish</td>
<td>General Waste</td>
</tr>
<tr>
<td>Societal</td>
<td>Aesthetics, Wildlife, Wetlands</td>
<td>Waste Sink</td>
</tr>
</tbody>
</table>

All of this means that there are a vast number of interactions which must be considered when identifying the most efficient combination of uses of a freshwater ecosystem. Each user consuming water reduces the quantity available to others for consumption. Additionally, the reduction in quantity means that waste dumped is less diluted, so the capacity of the resource as a waste sink is reduced.

The multiplicity of ways which uses affect both the quantity and quality of water available to other users and uses is illustrated in the matrix in Figure 5. This matrix demonstrates that different forms of uses conflict with others.
in different ways. For example, it is unlikely that a recreational use such as swimming will significantly impact a downstream use such as irrigation. This is indicated in the matrix by the presence of a low value of $a_{15}$ where the recreation row crosses the agriculture column. On the other hand, if the situation were reversed and the water was first used for irrigation it might have sever impacts on downstream recreation use. In this case the box where the agriculture row intersects with the recreation column has a value of $a_{31}$. Thus it is important to note that the matrix is not symmetrical.

### Figure 5 Matrix of impacts of users

<table>
<thead>
<tr>
<th>Users</th>
<th>Recreational</th>
<th>Domestic</th>
<th>Agricultural</th>
<th>Industrial</th>
<th>Forestry</th>
<th>Societal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreation</td>
<td>$q_r$</td>
<td>$a_{11}$</td>
<td>$a_{12}$</td>
<td>$a_{13}$</td>
<td>$a_{14}$</td>
<td>$a_{15}$</td>
</tr>
<tr>
<td>Domestic</td>
<td>$q_d$</td>
<td>$a_{21}$</td>
<td>$a_{22}$</td>
<td>$a_{23}$</td>
<td>$a_{24}$</td>
<td>$a_{25}$</td>
</tr>
<tr>
<td>Agriculture</td>
<td>$q_a$</td>
<td>$a_{41}$</td>
<td>$a_{42}$</td>
<td>$a_{43}$</td>
<td>$a_{44}$</td>
<td>$a_{45}$</td>
</tr>
<tr>
<td>Industrial</td>
<td>$q_i$</td>
<td>$a_{51}$</td>
<td>$a_{52}$</td>
<td>$a_{53}$</td>
<td>$a_{54}$</td>
<td>$a_{55}$</td>
</tr>
<tr>
<td>Forestry</td>
<td>$q_f$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Societal</td>
<td>$q_s$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Also note that users affect both members of their own sector and members of all other sectors too. This creates competition for water among sectors and between sectors. We saw above that users may be separated by boundaries and this reciprocity of effects will cause competition for water across these boundaries too.

The huge number of interactions means that any attempt to manage a shared freshwater resource would have to take into account every single one of these different connections to achieve the optimal outcome. Note also that this matrix is very simplistic in that it only reflects the groups of users, not the array of uses that each group may have of freshwater ecosystems. Not only will the magnitude of each effect differ between users and uses, but it will differ across time and space. A centralised regulatory management system to take account of this heterogeneity would be too complicated to be serviceable. Thus government is also as likely as the market to fail in effectively managing freshwater ecosystems.

Note that one of the key failures that will result from this misallocation is likely to be the failure to provide for the societal uses of freshwater ecosystems. Many basic environmental functions are dependent upon the
proper maintenance of this system, and the allocation of a flow of goods and services into such things as species habitat, wetlands, and forests. If water is misallocated then it is likely to be not only an economic loss but an environmental one as well.

### 3.3 Synthesis of the problem

The main barriers to the successful management of freshwater resources are:

- Complexity of interactions and linkages (rendering market solutions difficult)
- Multiplicity of boundaries (rendering governmental solutions difficult)

These factors combine to mean that the establishment of a management programme accepted by all users is a very complex process that will require extensive bargaining over the shares of gains before it is implemented. In the meantime, society will remain at the non-cooperative equilibrium, where the allocation of the resource is socially inefficient. The implied continued wasting of the resource means that the bargaining frontier shifts in and the potential gains from any agreement gradually decrease with time.

The absence of an optimal system of water management means that freshwater will become even more scarce. Competition for use will thus increase and conflicts are likely to become even more intense. As freshwater becomes more valuable, there will be even more incentive for individuals to attempt to appropriate more than is socially optimal. Without the establishment of a management institution that can facilitate co-operation in water management, water users are trapped in a vicious circle of scarcity and environmental decline.

### 4. Problems in Managing Freshwater Ecosystems

This section sets forth a more detailed listing of the various problems that make it difficult to manage the complexities within freshwater ecosystems. The first subsection summarises the basic framework of the chapter: structural inefficiencies; the management of these inefficiencies; and the difficulties in achieving this management. The remainder of the subsections provide detailed discussions of the difficulties that prevent the achievement of efficient management structures regarding freshwater resources.

#### 4.1 Basic Principles

The basic principles of freshwater ecosystem management are as follows. First, in the absence of coordinated resource allocation, there will be
observable inefficiencies in the use of freshwater resources and there will also be many unobserved inefficiencies by reason of the misallocation of the resource between activities. Second, in order to correct for these inefficiencies, it is necessary to create an institution that will effectively restrict aggregate use and re-allocate it toward its first-best uses. Thirdly, even though there will be societal benefits from achieving this reallocation, it will be difficult to implement on account of the complexities of resource reallocation in such a complex environment.

4.1.1 Basics of Structural Inefficiencies

One inefficiency from resource mismanagement will be the misallocation of resources, away from societally preferred activities and toward others. This is the problem of resource misallocation referred to previously. Structural inefficiencies also result in the over use and wastage of a scarce resource. These costs from imperfect management structures may be categorised under the headings: hoarding, stock inefficiencies, and over-capitalisation.

*Hoarding* results from a situation where the individual extracts as much of a resource (water, fish, timber) as he can use or store because of uncertainty about the future availability of the resource. This is because if the user does not extract the resource today, then his neighbour or another user will. Thus the incentive is to extract today rather than to conserve the resource for the future. This is illustrated in the case of Edwards Aquifer in Texas (box 3) where there is no incentive to use the pumped water efficiently as there is no private added benefit of doing this.

While many of the goods associated with freshwater ecosystems are renewable (fish, peat, timber) their ability to replenish themselves is undermined by over-extraction. This is a *stock inefficiency*. For example, while precipitation and groundwater flow serves to recharge an aquifer, if the level of water extraction is higher than the inflow, the net input is negative. As a result, the level of the aquifer will fall and each person pumping water must sink deeper wells to continue extracting at the previous rate. This imposes added costs on the other water users, external costs which are considered in the consumption decision of the individual.

The excess extraction of water and the costs imposed by stock inefficiencies means that the *level of capital investment* in extractive machinery is much higher than is socially optimal. Society would benefit if some of the capital resources used to exploit the water over and above the optimal level were instead invested in the design and implementation of a cooperative management structure.
Resource misallocation is more difficult to quantify as it results from the absence of pricing mechanisms and the inability to institute values for certain goods or services. However, the cost of misallocation is very real because every time that the resource is placed into a less-preferred use, it incurs an implied cost equal to the foregone value from the societally preferred (but not pursued) use. This is the reason that it is essential to value the flows that society receives from uses such as wildlife conservation and habitat conservation, because without these values we do not know the opportunity costs of misallocated water resources.

4.1.2 Basics of Management Structure
We can define efficient management in two ways. First, effective co-operation between management entities and/or clearly defined and enforced ownership structures would address and eliminate the costs outlined above. (In terms of the previous section cooperation would allow society to move from the Nash Equilibrium, $\times$, onto the bargaining frontier.) The goal of the basic principles of management is to provide for the creation of structures that eliminate these costs of resource misallocation.

One definition of the required management structure would be that it must perform certain basic tasks that would restrict and re-allocate the use of water resources. These are to enforce a limit on aggregate use, and to create a mechanism for allocating that use appropriately between the competing
uses. In order to create such an institution, it is necessary to perform four sub-tasks. These tasks for resource management are: the determination of the efficient level of the resource flow available; the determination of optimal allocations to individual uses; and the monitoring and enforcement of these allocations. Box 4 demonstrates the basic kind of management system needed for the optimal allocation of one good derived from freshwater ecosystems – water.

Box 4 Requirements for Managing Water Resources

(a) Total Available in Terms of Rates of Flow
Since the water available at any point in the hydrological system depends on the time, it is essential that the rate of flow of water is understood so that it is not overexploited at any point. The rate of flow can then be determined so that the rate of extraction of water does not exceed the rate of input.

(b) Optimal Rate of Aggregate Use
The level and rate of use that maximises social welfare must be decided upon. While in wet months a high aggregate rate of pumping from an underground aquifer may be possible, it may be necessary to keep a steady rate of extraction all year round to ensure availability of supply even when there is no rain.

Box 4 (continued)

(c) Shares of Individual Use
Once the optimal aggregate rate of use has been determined, it will be necessary to decide in what proportions users can use the resource. It is likely that priority will be given to those users that have relied on the water for the longest. However, it is essential that these shares are flexible; in time the social returns to water use will differ between categories of user and only if individual shares are transferable will the water be put to its highest value use. It is probably this element of the agreement that is likely to be met with the opposition, especially when historical allocations of freshwater use are altered.

In addition, some users such as industry will have a similar level of water demand all year round whereas use for irrigation will be concentrated in the dry months. It is essential that the different rates of individual use are taken into account so that the aggregate rate of use meets its target.

(d) Monitoring and Enforcement
If parties are to sign an agreement they must believe that other signatories will stick to their part of the bargain, otherwise those who comply will lose out at the expense of others. A system of penalties for non-compliance will require the careful monitoring of water use activities to ensure that behaviour is truthfully reported and the efforts of some are not undermined by others.
4.1.3 Basic Complexities
The essence of any resource allocation problem is for the group of interacting users to reach agreement on a method for reallocating the resource that will move that group to the societal optimum. In the simple situation, where there is only a small number of identical users who all face the same kind of incentives and motives, the Coase theorem suggests that the socially optimal resource allocation can be reached by bargaining. In the case of the agricultural use described in section 3, for instance, it is possible that the agricultural user can be encouraged to take into consideration its impacts upon others (irrespective of the right to engage in that use). So long as other uses are of greater benefit, bargaining between users can reach the optimal resource allocation, $Q^c$, as described in Figure 6.

The Coase Theorem, however, is set in a context in which the resource involved affects only a limited number of players who possess symmetrical information about the situation and face low transactions costs to bargaining. In most cases involving water, however, these conditions are not met, presenting parties with substantial transactions costs, as defined in the section above. As indicated there, these costs increase with the number of parties involved, the need to exclude non-parties, the complexity of impacts and the heterogeneity of parties.

As the number of parties increases, so does the range of costs and benefits that must be taken into account. Each user has a different set of concerns about any proposed management structure, and will try to get the best deal for itself. It is therefore difficult to assess the real costs and benefits to each party and prevent parties from overestimating the costs to themselves.
The public good aspects of freshwater ecosystems mean that it is difficult to exclude non-parties from the benefits of cooperation. As a result, it is hard to prevent any non-signatories from benefiting from the improved ecosystem management. Players may foresee this and so deliberately refuse to sign, relying on the fact that the compliance of others will make them better off regardless. This is known as free-riding. Attempts to calculate the opportunity for free riding and how prevent it will impose an extra burden.

The complexity of interrelationships in freshwater ecosystems use means that it is difficult to identify exactly who has what effect on the ecosystem. It is essential that all interactions between both users and uses are taken into account if the socially optimal level of consumption is to be found, but this is practically impossible in the context of systemic resources such as freshwater systems.

Furthermore, the users have very different perspectives on the issue (different prior rights, different interactions), and competition between them imposes an extra cost on contracting. Just as the number of users increases the costs of contracting, the more heterogeneous the users, the higher the costs of contracting. The more kinds of uses and users, the greater the heterogeneity of interactions and thus the broader the range of interests that need to be taken into account, so the more expensive bargaining will be (Libecap, 1989). Therefore, the basics of a management institution may be prevented from coming into existence by reason of the basic complexities of the freshwater ecosystem context. The remainder of this chapter will illustrate these points in much greater detail.

4.2 The Simplest Case

We will spend the remainder of this chapter examining the hurdles that stand between a group of users and their move to the socially optimal resource allocation with regard to a shared freshwater system. The simplest case is where the external effects experienced by each user are identical and reciprocal. Here all users have an incentive to improve the situation through self-motivated co-operation. Where each party undertakes the same kind of restrictions, the benefits are shared symmetrically and equally. This built-in reciprocity within the resource system makes cooperation much easier to achieve.

For instance, take the case of an aquifer that supplies water to a group of identical users who rely on it for identical uses. In the case where all users are at the same point in the hydrological system, require the water for the same purpose and are under the same jurisdictional control, each faces identical incentives to co-operate. If one player reneges on their undertaking
to manage water use, the threat of retaliation by other users at a later stage will be enough to make the agreement self-enforcing. Since all stand to gain from co-operation and will be punished in the long run for misbehaviour, the gains to contracting far outweigh the costs and an agreement should result (Barrett, 1990). Thus agreement is easiest where users are at the same point in the system, have the same uses, and are under the same jurisdiction. Box 5 gives some examples of agreements reached over water usage.

Box 5 Examples of Contracting for Water Management

- While at the basin level, the Mississippi crosses many state boundaries, its three tributaries supply a much smaller area. In addition, the external effects of water use are unidirectional between users; users of the Lower Mississippi, e.g. at Memphis, will be affected by pollutants from riparians on the upstream tributaries, Cincinnati users on the Ohio, for instance. However, Cincinnati users are not affected by the uses of citizens of Memphis. The straightforward nature of this interaction meant that even before the Environmental Protection Act, agreements such as the ‘Ohio River Compact gave downriver residents certain rights with respect to upriver pollution’ (Anderson and Hill, 1997: 50). The relatively simple nature of the situation allowed agreement to evolve. Source: Anderson and Hill, 1997.

- Water Users Associations are common in areas where there are a large number of irrigators, who all share the same water resources. For instance, in Indonesia, the Subaks of Bali developed rules to control both the amount of water individuals could extract and the financial and labour contributions that users must make to maintain water systems. Such a decentralised organisation requires a ‘cohesive social structure that discourages any overt conflict’ (Dinar, 1997a:30) to effectively ensures that the private and social marginal cost curves converge. The success of the organisation in terms of efficiency of use is unclear, however the organisational structure has been sustained over time, ‘providing users with a longer time horizon to increase the payoffs to cooperation’ (Dinar, 1997a:30). Source: Dinar, 1997a.

Co-operation has sometimes been encouraged by simplifying a more complex situation, for instance by involving only a proportion of parties in

Box 6 Water management solutions ‘incomplete’ co-operative solutions

- Although the Nile flows through nine countries (Gleick, 1993), in 1959 the Nile Waters Agreement was signed between only Egypt and Sudan. Since 86% of the flow into Egypt passed through Ethiopia first, these riparians were motivated to come to agreement on the share of the flow that Ethiopia, could demand. Since Sudan has never yet withdrawn its full allocation, the full constraints of restricted consumption on Ethiopia have not yet begun to bite. However, as demand in all riparian countries grows, the pressure on the Nile waters will rise and in the longer term it is unlikely that Ethiopia will acknowledge the restriction on supply, since it was not party to the agreement. This will render the agreement worthless as despite the investment in water management, by excluding one of the most fundamental signatories the resource can still be over-exploited.

the development of a management structure. This cannot lead to an agreement that is efficient in the long term, since all external effects and interests of all parties (required to reach the socially optimal outcome) are not included in the simplified situation. The complexity of a natural system cannot be assumed away through the creation of less complex institutional structures. The institution must be made as complex as the system itself. Box 6 illustrates this problem in the context of the Nile river.

4.3 Complexities in the Commons

In almost all cases, this sort of reciprocity is not built into the natural system. The group of users of a system seldom satisfies the requirements of same point, same use, and same jurisdiction. Instead there is some degree of heterogeneity between parties. Whatever their nature, differences between users increases the range of interests and thus demands. These must be considered and satisfied by any contract if it is to succeed.

4.3.1 Different Points in the System

One of the most common sources of conflict is that between upstream and downstream users within a freshwater ecosystem. At different points in the ecosystem the different users have no initial incentive to consider the effect of their activities on others. Although this externality is unidirectional, the large number of users can prevent a contract from being reached easily. Two examples of such a situation are provided in Box 7.

Box 7 Interaction between upstream and downstream river users

Daugavpils, Latvia: Daugavpils is the second largest city in Latvia, drawing 70% of its water supply from the Daugava river. The discharge of heavy metals and oil spills into the river upstream in Belarus affected the quality of water available for consumption in the municipality. In addition, the municipality faced the discharge of effluent by the city's own water treatment plant, which failed to meet the standards of the Helsinki Commission. Since the Daugava flows from Daugavpils, to Riga and then into the Baltic Sea, the quality of the water available to another set of users was also affected. Source: Merrett, 1997:70.

The Danube: The Danube, at 2850 km, is the second longest river in Europe, its basin covering 17 countries. The effect of upstream activity thus often affects the population of a different country whose well-being is rarely taken into account by foreign governments. The town of Bratislava in the Slovak Republic suffers pollution from discharge into the river by the water users upstream of it; by the time the river has flown through Austria and meets the Morava that runs through the Czech Republic, the water contains ‘sewage discharge pathogens, nitrates from fertilizer use, heavy metals, mineral oil discharges, chlorinated solvents and acid rain’ (Merrett, 1997:23). In order for the residents and industries of Bratislava to be able to make use of the water, it must be treated, a financial burden imposed by the upstream users. Here then, the non-consumptive use of firms in the Austria and the Czech Republic affect both consumptive and non-consumptive users downstream. Source: Merrett, 1997: 115.
4.3.2 Different User Sectors
The range of uses involving a freshwater system also affects the degree of complexity. The historical concentration of water consumption by irrigation use in many arid and semi-arid countries means that the water rights of an area historically fall to the agriculture and rural sectors. As the urban population grows, the demand for households and industrial uses increases, creating pressure on the resource and diversifying the characteristics of the users. Generally, achieving cooperation with a number of different user types is more difficult. Some examples of these difficulties are demonstrated in the cases in box 8.

**Box 8 Inter-sectoral Competition for Freshwater Ecosystem Uses**

**Agriculture and industry**

**Turkey**: In Turkey, the share of agriculture in national output has decreased from 27.6% in 1977 to 18.1% in 1990. Rural to urban migration has meant that over the same period, the industrial share of output increased from 19.8 to 29.2% and the demand for water by industry has gradually increased. Since the value of industrial output relative to that of agriculture has increased, a transfer of water from agriculture to industry would be efficient. However, the historical allocation of water rights by government has tended in favour of agriculture.

*Source: Bilen and Uskay in Le-Moigne, 1993.*

**Forestry and floodplain users**

**China**: The floods on the Yangzi river in the summer 1998, were estimated to have killed 3,000 people. While the overcrowding of the floodplain exacerbated the situation, it was deforestation upstream on the Yangzi River itself and its tributaries that were blamed as the primary cause. The bare slopes exposed by logging combined with soil erosion ‘help explain why, even when the summer rainfall has not been spectacularly high, the volume of water barrelling down the Yangzi has risen during the 1990s’ (*Economist*, 26/09/98).

**Households and agriculture**

**Ukraine**: The Dnipro river is the largest river in the Ukraine, providing drinking water for 33 million people, two thirds of the population. Approximately 20 million m$^3$ of untreated sewerage and effluent are reported to be dumped into the river each year. This both causes health problems and has also reduced the agricultural output of land irrigated from the river.

*Source: MacIvor, RFE/RL, 28/01/99.*

**Wildlife and irrigation**

**California**: In 1992, the Central Valley Project which usually carries water to farms in the San Joaquin Valley was suspended in order to prevent the water level in the spawning ground of the chinook salmon falling too low and allowing the fish to overheat and die. The CVP provided 8m acre-feet, approximately a third of total irrigation water to farmers, in an average year, but in order to protect the fish, only 2m acre feet were provided in 1992.

*Source: Economist, 22/02/92.*
4.3.3 Different Uses
The type of use can also vary within sectors. As mentioned in section 3, users in each sector may derive a number of benefits from the freshwater ecosystem. For example, a farmer may derive benefits from irrigation, improved soil and household water consumption as well as direct consumption of fish, timber or fuelwood. The same farmer may also intrinsically value the freshwater ecosystem. Thus there could be a large number of uses associated with this single user and these may not be the same uses as the uses associated with the farmer next door. Some real-life examples of this are provided in box 9. Hence complexity of interaction arises within sectors, as well as between them.

**Box 9 Competition for water between uses**

**Agriculture**

**Czech Republic**: As a result of the intensive irrigation policy implemented under the Communist government, land throughout the Czech Republic became water logged. As a consequence, heavy rains could not be absorbed by the soil, causing flooding which affects a huge variety and number of parties on the floodplain. In the floods of July 1997 in northern and eastern Moravia, 46 people were killed and thousands were left homeless. The flooding affected agricultural uses too as crops and livestock were washed away, causing losses of approximately $400 million due to damage to agriculture and water supply facilities.

Source: Naegele, RFE/RL, 18/03/97.

**Forestry**

**China**: Soil erosion as a result of deforestation is a serious problem on the Loess plateau; although annual rainfall is only approximately 20-55 mm, over 1 billion tonnes of soil are washed into the Yellow River each year which reduces the natural water storage capacity of forestry land.

Source: Economist, 26/09/98

**Households**

**Lithuania**: The quality of drinking water in Siauliai, Lithuania suffers from the disposal of raw sewerage into gutters, streets and yards by households which then pollutes the drinking supply. Since only a small proportion of households are connected to the municipal sewerage system and the provision of tanks for its disposal are inconvenient, neighbours turn a blind eye to the behaviour of others.

Source: Moffett, RFE/RL, 15/03/97.

4.3.4 Different Jurisdictions
Complexity of interaction also increases with the number of distinct management units that are involved. Freshwater ecosystems often cross a number of management boundaries. Consequently, users and uses at different points in the system are also under different jurisdictional control.
Hence users may affect other users in different localities, regions and countries. Some examples of this are provided in box 10.

Box 10  Conflicting water use between jurisdictions

- **Rural and urban**  
  **Chile:** The Azapa Valley in Chile contains an unconfined aquifer on which the city of Arica and the surrounding rural area rely for water supply. In 1993, the ‘Water Supply and Sanitation Company of Tarapaca’ (ESSAT) was given capital to expand urban water supply. The pumping of the aquifer increased to such an extent that a ‘recent study has concluded that at current withdrawal and recharge rates the remaining life of the groundwater storage is less than 20 year’ (Simpson, 1997:54). While the municipal government is committed to expand the supply of urban drinking water, the falling level of the aquifer will reduce the water available for irrigation.  

- **State and nation**  
  **Canada:** Conflict between the national government of Canada and the province of British Columbia meant that although by 1944, the US and Canada ‘had come to understand their mutual interest in developing hydro-power and flood control facilities on the Columbia River’ (Barrett, 1993), the Columbia River Treaty which involved only these two countries, was not signed until 1961 and then took until 1964 to ratify. One of the reasons for this was that the individual province realised the benefits it could gain from storing water and then using it to produce hydroelectric power within that province. The Canadian government however, looked at the project at the basin level and so could appreciate the benefits to all parties concerned of installing the power plant over the US border. Source: Barrett, 1993: 25-26.

4.3.5  Competition as a barrier to cooperation

In some cases the competitiveness between the parties will act as a barrier to agreement even if it is in the best interest of all of the parties involved. In order for cooperation to be achieved, the parties must be willing to confer a benefit on the others, as well as upon themselves. Sometimes the climate of competition is so intense that it is difficult for the parties to agree to any form of cooperation. In other cases the parties cannot agree because of their unwillingness to make anything other than the “best possible deal”. Such competitiveness in the arena of cooperation can delay or prevent cooperative resource allocation. Box 11 describes two such situations.
Box 11 Conflicts due to competitiveness

Nation and Nation – Unwillingness to confer benefits on rivals
In Latin America there are 58 internationally shared water basins and in many cases agreements have been formulated to legislate for their use, such as in the Amazon Basin between Bolivia, Brazil, Colombia, Ecuador, Peru, Surinam and Venezuela (Lee, 1995). However, the international intervention proposed in these agreements has been successfully implemented in only a minority of instances.
The concentration of population, political inclination and economic activity in the urban centres has left international water resources, located at the border, ‘marginal to the main focus of development for most of the countries in the region’ (Lee, 1995:553). However, the lack of continued international co-operation in river basin management is mainly due to the historic reluctance of the Latin American countries to integrate with neighbours perceived as both political and economic rivals. Source: Lee, 1995

Nepal and India – Making the best possible deal
The rivers of the Nepalese Himalayas could generate approximately 83,000 MW of electricity a year for export to India, but Nepal fears the political consequences of such a sale would be to increase its already strong dependence on its neighbour. Nepal stands to gain desperately needed income from the export of electricity, but the player feels it does not hold enough political clout to get the most out of an agreement with India. Bargaining over two potential projects has now taken over 20 years. The two countries cannot agree on the mechanism for setting the price of electricity; Nepal would prefer to maximise profit, while consumers in India would like as low a price as possible. In addition, India would stand to benefit from the management of the water in Nepal as flooding downstream would be reduced. Nepal therefore expects payment for this benefit, while India claims that it has already established flood controls and so the new developments would be of no benefit. Nepal has encouraged involvement of the World Bank as a third party to try and even up the balance of power in negotiation. Still, a compromise is yet to be reached. Source: Economist, 22/06/91.
Competitiveness, relative to cooperation, is also dependent on the perception of relative bargaining power in negotiations over resource allocation. One of the key factors in any agreement is the belief of parities that they can get a fair deal, and thus their perception of the bargaining environment is key. Heterogeneous parties are unlikely to possess symmetric information concerning the natural and institutional conditions they face. This asymmetrical information will then introduce a degree of uncertainty into the bargaining process. The example in box 12 demonstrates just such a situation.

The asymmetry of information may allow rent seeking by individuals through the misrepresentation of their costs and benefits. The motivation of individuals to maximise their potential gains will result in increasingly cut-throat contests for allocations, further reducing the opportunity for straightforward negotiation. This is demonstrated in the case of the establishment of a water bank to act as an intermediary between buyers and sellers, as established in Idaho. Users are able to rent water for a price stipulated by the bank. By sharing the revenues from sales in proportion to the quantity of water offered rather than that sold, suppliers are given an incentive to raise the amount of water they offer to sell over and above the efficient level (Anderson and Hill, 1995: 85).

**Box 12 Oregon: failure of salvaged water legislation due to asymmetric information**

In 1987, legislation was introduced to encourage the efficient use of water in the State of Oregon by legalising the sale and use of salvaged water. It was hoped that a market in salvaged water would develop, encouraging owners of waste water to salvage it so long as the price offered for the water covered their costs. Despite the apparent advantages of the scheme to both buyers and sellers, only 3 small plans for water saving had been suggested by 1993. Government approval was required for any scheme, and players believed that this invasive monitoring role would provide local authorities with information that they could use to redress water allocations at a later date. Irrigators feared that in admitting to owning waste water, if government policy changed, the future size of their right would be reduced. The lack of information available to players about the time horizon of the policy, meant that they withheld information which further increased the asymmetry of information, negating an agreement with apparent benefits to both parties.

Source: Anderson and Hill, 1997: 8.

This problem of asymmetric information is likely to be particularly acute at the national level where states must take into account not only the constraints facing the domestic government, but also those facing the foreign country. The greater the range of responsibilities of the entity, the
harder it is to predict their bargaining stance. While nations stand to lose more if an agreement is not reached, it is also extremely important that such parties save face and protect their national sovereignty (Benvenisti, 1996).

4.3.6 Enforcement and monitoring

Monitoring and enforcement is a sine qua non for the existence of a concrete and effective management institution. Parties are able to continue to exploit resources in an unrestricted fashion, if their nonconforming conduct is neither observed or punished. In the case of freshwater resources, as with all other resources, this is a problem particularly where the resources or systems (or their flows of benefits) cross international boundaries. Since many of these systems do generate flows that cross international lines, the international regime is especially important for the management of these resources.

One of the most significant factors affecting the development of effective management institutions in the case of freshwater ecosystems is the lack of universal agreement on the legal rules for ownership rights. While specific jurisdictions may have rules by which they abide, these laws differ between nations, states and cultures; when two different parties are in conflict, there is no clear way to determine the equitable, acceptable allocation of ownership rights in the absence of a common set of principles. The failure to agree on such common principles prevents the attainment of cooperative outcomes (see box 13).

### Box 13 River Lauca: failure to enforce international law

The River Lauca has its source in Northern Chile from where it runs across the Bolivian border to Lake Coipasa. Plans by the Chilean government in 1939 to increase water use for irrigation along the upstream reaches of the river were met by opposition from Bolivia who feared that the reduced water supply caused by their upstream neighbours would have an adverse effect. Consequently a joint commission was established to assess the effects of the proposed plan on both parties and in 1949 the commission found that no harm would be caused to Bolivia. Bolivia was unhappy with this judgement and continued to contest the decision until over 15 years later when diplomatic relations between Bolivia and Chile ceased. A failure to abide by the decisions of the international body and an unswerving demand to keep face rendered all co-operation and negotiation useless. Source: Lee, 1995: 545.

This problem has been addressed recently at the international level. The Watercourses Convention, adopted in 1997 by the United Nations General Assembly requires that international watercourses must be managed by the combined agreement of the riparian states. The Convention requires that use of international watercourses must be determined in an ‘equitable and
reasonable manner’ but it is left to the agreement of the individual users to define what kind and level of use is equitable. If a dispute cannot be resolved even after ‘due diligence’ has been exercised, then the convention outlines ‘residual rules’ for the management of the resource, but there is little guidance available for nations on how to come to a mutually beneficial agreement (Hey, 1998).

For any proposed agreement to be credible it is necessary to monitor to ensure that parties follow the rules, and to punish if they do not. At the local level, this can taken the form of individuals designated and recognised by the community specifically to monitor the activities of users. One such example is provided in box 14.

<table>
<thead>
<tr>
<th>Box 14</th>
<th>Huerta Irrigation Systems</th>
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<td>In Spain, near the city of Valencia, for example, an irrigated area called a <em>huerta</em> is clearly delineated close to a town within which water resources are managed by close community co-operation. The rules for the management of water within this area were developed 550-1000 years ago but are flexible; ‘farmers have continued to meet with others sharing the same canals for the purpose of specifying and revising the rules that they use, selecting officials, and determining fines and assessments’ (Ostrom, 1990: 69). Careful monitoring ensures that only the assigned allocations of water are being used by farmers. Since the scarcity of water means that the temptation to defect on the agreement is considered to be very high, ‘ditch-riders’ are paid to oversee the activities of all water users. The monitors are themselves watched over, answering to the governing body. Punishments for those who do not comply to the rules include fines, and also the humiliation of public disapproval. The success of this system of local monitoring is reflected in the infraction rate of only 0.008, but it would require too much time and labour for a larger scheme to implement. Source: Ostrom, 1990.</td>
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But at the national, regional and international levels it is most difficult to find a suitable monitor. In the Palestinian and Israeli conflict for water for instance, the joint management of aquifers is essential for their efficient exploitation. A joint Palestinian and Israeli study highlights the need for an international governing body to monitor and verify agreements. Such a body would have to be flexible so as not to infringe on sovereign rights, but also concrete enough to be effective. Without careful monitoring and enforcement, agreements cannot be sustained. The maintenance of co-operative solutions at the international level relies on the attainment of a satisfactory level of diplomatic relations between the parties, to generate confidence on both sides that parties will meet their responsibilities. Hence the balance that an international body must strike is a delicate one (Feitelson and Haddad, 1998).
Despite the importance of diplomatic relations as a precursor to the management of shared ecosystems, it is equally important to recognise that shared ecosystems also provide an important basis for the development of decent diplomatic relations. The long term nature of the interrelationships formed by shared ecosystem use provides an added incentive for parties to stand by their commitments since the threat of future retaliation may be enough, in some cases, to prevent parties from stepping out of line and reduce the need for monitoring and enforcement effort (Barrett, 1993; Ostrom, 1989). In effect, the complex commons of the world provide both the centres for international conflict, but also the opportunities and bases for the development of international cooperation.

4.4 Rent Seeking – Institutions Overlaid on Claims

Although society as a whole stands to benefit from co-operative freshwater ecosystem management, the instinctive reaction of individual bargaining groups is to get the best deal for themselves out of the process. In general, the individual negotiator often will be looking for ways to appropriate individually greater shares of the joint benefit, rather than ways in which to create the joint benefit. This behaviour is known as rent seeking, and it is a formidable barrier to the attainment of cooperation. This section details a long list of circumstances by which parties attempt to distinguish themselves from the remainder of the negotiators, in order to claim individually a greater share of the societal benefits from joint management. This wide variety of rules of entitlement, and the ways in which they are used to create individual claims of entitlement, illustrates the problems with attempting to create effective management institutions in realms where many pre-existing claims are overlaid.

4.4.1 Prior in use

When sharing a freshwater ecosystem, the advent of a user further upstream means that less water reaches the downstream users than they had initially appropriated. The fact that they were using the ecosystem first is often argued to give them the right to a maintained level of flow, or compensation if the resource is reallocated. This is called prior appropriation in use, and its complexities in application are demonstrated in the case of the Aral Sea.

The diversion of the rivers Syr and Amu Darya to provide riparian nations with water for irrigation resulted in the shrinking of the Aral Sea. In order to stabilise the level of the Sea, the riparians agreed to reduce the aggregate level of consumption, implying that countries such as Uzbekistan receive only a fraction of the water that they need to continue irrigating their cotton. As the population in upstream regions such as the Fergana valley increases, the upstream demand for water continues to rise. As the original user of the
flow within the tributaries, Uzbekistan maintains that it must still have access to enough water and will require compensation if upstream users reduce the flow reaching it (Economist, 21/10/91).

4.4.2 Prior in time

One way in which water users can consolidate their claim to freshwater ecosystem goods is based on the historical pattern of use. If users have managed to appropriate goods for their use first, they have obtained a valuable resource and obtain the right to claim compensation if the goods are reallocated to another user. This is called *prior appropriation in time* and is demonstrated in the case of water rights in the Imperial Valley.

The Imperial Valley just East of San Diego has less than three inches annual rainfall. However, in the early 1900s, a clerk appropriated a majority of the flow of the Colorado river to this area. As a consequence, ‘the 150,000 people in the Imperial Irrigation District (IID) are entitled to six times more water from the Colorado - about 3m acre-feet a year - than the 16m people of the Metropolitan Water District’ (Economist, 21/02/98). The appropriation of the right to water means that the IID can now offer to sell approximately 200,000 acre-feet of water a year to San Diego. Farmers would benefit from the sale of the water to the municipality, reflecting the true value of their early appropriation of the water (Economist, 21/02/98).

4.4.3 Appropriation in negotiations

The appropriation of shares of freshwater ecosystem goods through negotiation is likely to be one of the most difficult aspects of reaching a co-operative contract. Since each player wants to ensure that they get the best deal possible for themselves, plans for sharing the resource are likely to need revising several times. Although the community as a whole stands to gain from co-operation, the cost of changing the pattern of use will also have to be borne. Individual groups will have an incentive to try and free ride on the investment of others and so reduce the costs to themselves.

A variety of methods have been used to allocate freshwater ecosystem goods between users. In some cases an agreement can be reached, but whether this distribution will be optimal in terms of economic efficiency is questionable. For a solution to be efficient, the least cost reduction in use should be undertaken first and the good transferred to its most valuable use. It will be rare that users will be prepared to give up their right to the goods easily though and it is likely that bargainers will have to compromise in some way so that an agreement on the distribution of gains from co-operation can be reached. This is demonstrated in the cases presented in box 15.
Box 15 Cases of Appropriation Negotiations

The Nile
The 1959 Nile Waters Agreement between Egypt and Sudan allocated the estimated 84 billion m$^3$ water between the two states and downstream riparians, Table 4. Although 86% of water originates in Ethiopia, this country was not allocated any water under the agreement. While the two countries signing the agreement bargained between themselves to allocate what they believed to be an equitable share, the water needs of non-signatories were ignored.

Table 4 Water Allocations under the 1959 Nile Waters Agreement

<table>
<thead>
<tr>
<th>Country</th>
<th>Origin of Water</th>
<th>% Share under agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egypt</td>
<td>0</td>
<td>66</td>
</tr>
<tr>
<td>Sudan</td>
<td>minimal</td>
<td>22</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>86</td>
<td>0</td>
</tr>
<tr>
<td>Other riparian countries</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Evaporation and seepage losses</td>
<td>n.a.</td>
<td>12</td>
</tr>
</tbody>
</table>

Source: Whittington and McClelland, 1993: 82

Since no other country has ever contested the agreement, the failure of the agreement to encompass the needs of other riparians has not yet been tested. However, as the population of riparian countries grows, it is likely that bargaining over the distribution of rights to water will occur. Source: Whittington and McClelland, 1993.

Turkey and USSR
The 1927 convention between Turkey and the USSR agreed to share the water from water sources on the frontier between the two countries equally, half each. The simplicity of this agreement is attractive, although it is based on an assumed reciprocity that is unlikely to exist in most circumstances. Source: Barrett, 1993.

Rhine
In the 1970s, the nine riparian countries of the Rhine began to negotiate an agreement to control salt emissions into the river. A water quality standard was set first, aiming to reduce the concentration of chloride ions from 300 mg/l to 200 mg/l at the Dutch/German border. The standard was to be achieved by targeting a single potash mine at a cost of 100 million francs, of which France would contribute 30%, Germany 30%, Netherlands 34% and Switzerland 6%.

As the primary recipient of pollution, it was the Netherlands that stood to gain most from the reduction in salt levels, reflected in the highest percentage payment. Concentrations of salt in France and Germany were not significantly affected by the agreement, but they had a motive to sign on the basis of equity. Similarly Switzerland which was much further upstream stood to gain little direct benefit from the reduction in salt emissions. Their contribution reflects how players will recognise the longer term benefits of co-operation; since the game is reciprocal and repeated, if players co-operate today, it is more likely that others will co-operate with them in the future. Although it was later discovered that the costs had been hugely underestimated, this initial agreement served as the basis for the revised distribution of shares. Source: Barrett, 1993.
4.4.4 Rent seeking in making claims
The gains from prior appropriation of freshwater ecosystem goods in use and time means that individual users have an incentive to appropriate as much as they can. By engaging in prospective purchases, users increase the scarcity of the resource, and create a more complex environment within which management institutions must be negotiated and implemented. This is demonstrated in the case of the Murray Darling Basin Commission in Australia.

The Murray Darling Basin Commission evolved in South Eastern Australia to manage the dwindling capacity of the river basin to provide water. Reform took a piecemeal approach and different states within the basin introduced measures at different times. The lack of a comprehensive framework for water management meant that different regions provided different packages of water rights definitions and values. Some irrigators were able to exploit water that was not yet regulated but that they did not really need; the excess then became a valuable asset under new ownership rules (Anderson and Hill, 1997).

4.5 Problems in Freshwater System Management – Conclusion

This section demonstrated the complexities in the commons that typifies the problem of freshwater system management. The underlying problem has been sketched as the need for the development of joint management institutions that span the range of uses and users that are interconnected via any given freshwater ecosystem. Another set of problems emerges from the pursuit of the solution to this general underlying problem – these are the problems deriving from the complexity of the interlinkages (natural and institutional) between all of these various uses and users.

Natural complexity derives from the interlinkages created by the freshwater ecosystem. Linkages between sectors, and between different forms of uses within sectors, and between private uses and public uses – all of these linkages are important parts of the puzzle that must be resolved to move toward first-best resource allocation.

Institutional complexity derives from two sources. First the freshwater system itself spans a wide range of jurisdictions and their concomitant management rules and structures. The merging of these different management structures to recognise the commonality of the system is an important source of complexity. Another source of complexity is the layer of prior claims and expectations that such preexisting rules and institutions generate. Movement toward joint management structures must take place not within a vacuum but instead within this preexisting context of claims.
These complexities render simplistic solutions to freshwater system management out of place and impracticable. The solutions to freshwater system management must be found in the continuing evolution of institutions across preexisting boundaries to take into consideration the important impacts and interlinkages that occur across a wide ranging ecosystem.

5. Strategies for Addressing the Commons Problem

In this section we once again commence with the simplest possible depiction of the solution concept for this general problem. Then we proceed to analyse the implications for these solution concepts deriving from the complexity of the system itself. The difficulties with building the institutions necessary for implementing these solution concepts are illustrated by reference to various institutional alternatives (pricing, markets, regulation); however the fundamental message is the same. No simple institutional solution concept is available for the management of complex systems. This is an arena that is challenging because it urges the evolution of more complex and wide ranging forms of institutions for societal cooperation.

5.1 Basic Nature of the Strategy

It has been emphasised above that the interaction between freshwater ecosystem users and uses makes co-operative management of the resource essential. Figure 6 shows the interaction between the use of freshwater ecosystems, $q_n$, and the input of waste, $q_w$.

![Figure 6: Available Freshwater Ecosystem Goods](http://economics.iucn.org)

As users extract a quantity of freshwater ecosystem goods, $q_n$, and return a quantity of waste, $q_w$, the quality and quantity of freshwater ecosystem services available for others or for the future use has decreased.

We can see that the availability of freshwater ecosystem goods depends on both quality (a function of the amount of waste dumped) and quantity (a function of the amount extracted). Generally, as more goods are extracted,
the concentration of waste in the ecosystem increases and so the quality decreases. Thus the amount of freshwater services available depends on both the amount extracted for use and the concentration of waste in the remaining supply. It is equally important therefore to regulate both forms of use of freshwater resources, direct and indirect.

(1) FW services used = F(q_n) + W(q_w)

Here, the function F describes the relationship between direct usage of freshwater and the depletion of freshwater system services, and the function W describes the relationship between indirect usage of a freshwater system through economic activities that generate wastes within that system. In order to manage freshwater ecosystems efficiently it is essential that these relationships (between economic activities and freshwater services used) are understood and taken into account. The amount of services used will be dependent upon many aspects of the natural and economic context.

Once the relationship between economic activity and freshwater use is understood, then it is necessary to internalise the costs of these uses. First of all it is necessary to determine the true economic value of a unit of fresh water services. This will depend on all the other uses to which it may be put, and hence on the external effect of its use on others. The true social value of a marginal unit of freshwater services is termed its *opportunity cost*, i.e. the cost of the lost opportunities for its use elsewhere within the system.

Once the true value of the resource is know then an economic instrument should be designed to ensure that users of the water are now faced by the full cost. Water must also be managed for uses, direct and indirect; a regulation or management charge should be introduced so that users face the true cost of water for all uses.

Optimal management of a freshwater system therefore requires that the managers

- **Functional relationships.** Development of the relationship between economic activities and freshwater system services usage (F and W in equation 1 above)
- **Marginal Opportunity Costs.** Determine the value (or opportunity cost) of a marginal unit of fresh water use, \( \lambda \).
- **Optimal Charges.** Determine a regulation or charge that will internalise the true value of fresh water, \( \lambda \), for every extraction, \( q_n \), of fresh water. Also, determine a regulation or charge that will internalise the true value of water \( (\lambda) \) for each unit of waste generated that will contaminate a freshwater system, \( q_w \).
In theory, once these various relationships and values are known, it is then possible to establish a set of charges that will reallocate resource usage to its best social uses. (Swanson 1998)

5.2 Managing Complexity

The optimal management regime outlined above relies on the ability to accomplish the three steps outlined: functional relationships, opportunity costs, and system of charges. It is possible to write these out in abstract, but very difficult to understand what they might mean in practice.

The vast number of uses and users and the interactions of their impacts (as illustrated in the matrix in Figure 5) means that the true opportunity costs of any freshwater use is highly complex, and practically impossible to determine. Every kind of direct use has a different rate of implied freshwater services use, due to the range of interactions with other users. Indirect usage is even more difficult to untangle. The effect of waste generation on the ecosystem quality would depend on its capacity to enter the system, and the range of interactions between the waste and other uses of the freshwater system.

Any management regime must take into account this entire matrix of interaction in determining both the functional relationships and the opportunities of any given use. As a result, every use needs a different charge rate to reach the optimal allocation. This is possible in theory, but in practice it is likely to produce a system that is practically impossible to implement.

5.3 Economic Instruments and Complexity.

The complexity of the theoretically complete solution of freshwater ecosystem management will likely prevent its successful implementation. It is for this reason that a majority of economic instruments are constructed to manage a simplified environment. This implies that while freshwater ecosystem use and allocation is changed, the system is likely to only generate a small step toward the cooperative solution rather than to approximate the first best situation.

However, the implementation of an allocation mechanism can have a significant impact on the behaviour of users and therefore improve the efficiency of freshwater ecosystem use. By co-operating to design and implement a mechanism for use, the welfare of society can be improved if not maximised. To successfully affect behaviour, a number of properties are
desirable for any economic instrument in the context of complexity. These include flexibility, opportunity cost, predictability and equity.

It is essential that the mechanism be flexible enough to allow the allocation of freshwater ecosystem goods to adapt to fluctuations in demand and supply. Not only the right to freshwater ecosystem goods but also the goods themselves must be able to be exchanged. This ensures that the goods find the use with the highest marginal value. Additionally, for users to undertake long term investment in supply the mechanism must provide security, enabling users to be confident in their rights. While rights must be transferable to allow flexibility, users must believe rights will only be transferred if it is in their best interests.

A crucial aspect of any effective instrument for resource reallocation must be the objective of internalising opportunity costs. Despite the complexity of this task, institutions must attempt to value the goods at their opportunity cost in order for them to be allocated to their most valuable use. Thus the prices of the goods must attempt to approximate the full potential benefits of alternative uses including the effects on public goods. For this reason the valuation of the public goods elements of these services is crucial. (Swanson, Mourato and Day 1999).

Predictability is important because it indicates both a level of understanding of the system, and it indicates the importance of the future for inducing investments at the present. If users are not certain of the outcome of a water allocation process and do not fully understand the rules of the game, it is not possible for them to invest in the system or in the resource. While traditional mechanisms of water allocation do not result in the optimal outcome, the benefits of familiarity should not be underestimated.

Equity is important for enforceability in complex systems. If the allocation of goods is not perceived as ‘fair’ in that it does not make all consumers at least as well off, then it is unlikely to be accepted. Given the complexity of interlinkages within the freshwater ecosystem and hence the difficulty of monitoring and enforcement, the absence of acceptability will generate substantial amounts of nonconformance with the system. (Howe et al.: 1986). The remainder of this chapter examines a range of possible approaches, for their application in the realm of complex systems.

5.4 Rights and Entitlements

One way to internalise the externalities of an individual’s activities and to ensure that they take into account the full impact of their activities is to assign property rights to the components of the freshwater ecosystem. Once
individuals own a confirmed right to a proportion of the resource, they have
a private incentive to exploit that resource efficiently; only once ‘the…user
can be assured of continued use will the user invest in and maintain…systems’ (Howe et al., 1986: 440).

The aggregate level of consumption will reach optimal level only if the
rights are appropriately determined and allocated. Thus first the socially
optimal level of resource use must be determined and this divided into
appropriate rights to ensure that the total use is the socially optimal amount.

Furthermore, if a rights regime is to be accepted, it is essential that the
historical pattern of appropriation is taken into account. In order for rights to
ensure that the situation is Pareto improving, no player should be made
worse off. Thus if the allocation of rights means that some users are unable
to continue to use the freshwater ecosystem, the equity criterion has not
been met. The case of water rights in Japan is interesting in these regards.

In Japan, local communities recognised investment in water supply by local
people when resolving water conflicts during droughts. The introduction of
the Old River Law of 1896 formalised the allocation of water; customary
rights were recognised by this law, ensuring that local custom was respected
and an equitable allocation of water use maintained. However, to ensure
long term economic efficiency, modifications to these rights will be
essential. For example, many customary rights dictate the kind of equipment
that can be used rather than the volume of water that must be extracted. In
addition, as customary rights as regards upstream and downstream use
differs between localities, as competition for water grows, it will be
necessary to resolve conflicts through a unanimously agreed set of rules
(Nakashima, 1993).

The careful and transparent identification of the exact entitlement and
responsibilities associated with the rights is essential. But the unexpected
repercussions of some stipulations should also be noted. For instance, a
requirement that the failure ‘to use a water right for a set number of years
can lead to the right’s forfeiture or abandonment’ (Anderson, 1997:3) would
at first sight seem to prevent players from claiming rights speculatively. In
actual fact, the limit can reduce the time horizon of the holder and
encourage the holder to use water simply to ensure their eligibility for the
right. The example of water rights in the Canary Islands is instructive.

The clear and distinct definition of water rights in the Canary Islands has
meant that conflicts over water allocations have been limited. While surface
water belonged first to the crown and then later to the state, groundwater
‘belonged to anyone willing to invest in the structures needed to bring it to
As a result, even though the aquifers were ill defined and so the discovery of water expensive, private investors put capital into locating and exploiting the water.

The allocation of a permanent right to the flow of water to the successful explorer made a ‘wet’ well or gallery a highly valuable resource. The large number of wells meant that a competitive market in both water rights and water developed. The success of this particular market system was seen when lack of rain in the early 1990s caused a sever water shortage in peninsular Spain, a supply shortage that was averted in the Canaries due to the market incentives, facilitated by the allocation of water rights (Simpson and Ringskog, 1997).

Rights to pollute can also be issued to ensure that the concentration of waste in the ecosystem does not exceed the socially optimal level. Since the type of pollutant, location of deposition and kind of use will all affect the health of the ecosystem, rights must take this heterogeneity into account.

Once the rights to use have been determined, the players in the game are defined and it is clear who must take action to prevent the degradation of the ecosystem. But rights alone do not ensure efficient use of the ecosystem.

5.5 Markets in Rights

To achieve an economically efficient outcome for society, it is essential that the rights to use the freshwater ecosystem’s goods belong to those activities with the highest marginal social benefit. In a majority of cases, the numbers of users, the heterogeneity of their interests, the asymmetry of information available to the agency determining the rights and the need to ensure an equitable allocation, will result in an initially sub-optimal allocation of rights. The facilitation of a free market for rights would allow low value users to exchange permits with high value users, being paid the market price for the ecosystem’s goods transferred and therefore being fully compensated for the loss of the right. In the Canary Islands example above a market for water and water rights evolved organically due to the large number of users and the obvious benefits of co-operation to them all. In a majority of situations a centralised agency may be needed for such an institution.

For a market in permits to allocate rights effectively, the following conditions are necessary. The prior agreement of rights and their clear definition is essential for any trade to take place. Secondly rights must be valid for a long enough period that owners can assign a value to them. Information about the exact nature of rights and the rules of trading must be clear so that when assessing potential trades, both buyers and sellers
understand the full implications of the situation. The information available must include the nature and scope of the rights (Dinar, 1997a).

So long as transactions costs are low and an infrastructure for the transfer of both rights and the physical transfer of water has been developed, it is to be hoped that a market for water rights can develop (Anderson, 1997). This is demonstrated in the example in Box 16.

Complexity in the commons continues even after the development of marketable rights regimes. For the system to be societally efficient, the externalities of all transactions must be taken into account by both buyer and seller so that the price of a permit reflects the full social value of the ecosystem. This is especially complicated in the case of freshwater ecosystems where the number and the variety of uses make interaction so complex.

When a trade involves a change in use of the ecosystem, it is necessary to ensure that the full implications, including externalities, of this trade are reflected in the price. Some markets have therefore been structured to prevent the transfer of ecosystem components such as water between uses, but the most likely effect of this is to reduce the number of potential transactions and prevent some pareto-improving transactions from taking place. Table 5 illustrates the nature of approved water rights transfers between 1975 and 1984 in the US; while many of transfers are for the same use, a significant proportion allow a change of use, especially from agriculture to industry or households.

<table>
<thead>
<tr>
<th>State</th>
<th>Agriculture to Agriculture</th>
<th>Agriculture to Non-agriculture</th>
<th>Non-agriculture to Non-agriculture</th>
<th>Non-agriculture to Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>42</td>
<td>22</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>California</td>
<td>35</td>
<td>26</td>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td>Colorado</td>
<td>10</td>
<td>75</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>New Mexico</td>
<td>41</td>
<td>47</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Utah</td>
<td>34</td>
<td>24</td>
<td>42 (From Non-agriculture to any)</td>
<td></td>
</tr>
<tr>
<td>Wyoming</td>
<td>24</td>
<td>73</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

In addition to reducing the economic efficiency of the market, the complexity of regulations necessary to account for heterogeneity also
presents potential parties with transactions costs so high that transactions do not take place. This is true in the case of the Fox River in the US.

Ten pulp and paper mills and four municipalities discharge waste into a 22 mile stretch of the Lower Fox River between Lake Winnebago and Green Bay in Wisconsin. Tradable discharge permits were allocated to existing polluters in the hopes that water quality could be improved through the least cost reduction in discharge. Ex ante studies highlighted a fourfold difference in abatement costs between firms, suggesting that large cost saving could be made. In actual fact, only one trade has ever taken place.

The main cause of this inactivity has been the complex set of rules and regulations within the system. These imposed transactions costs on negotiators, reducing the benefits of permit transfer and creating barriers to trade. Each trade had to be approved which took time and money. The exact rules to trading were complicated to incorporate different kinds of pollutant, emitted at different times and at different place on the river. This made potential transactions unclear and so polluters were reluctant to propose transactions that they believed would be deemed be illegal and have wasted time and money. (see also Box 17 below)

Box 17 Complexity in Tradeable Permit Regimes – The Second Sulphur Protocol in Europe
Unlike the US sulphur trading program, the European sulphur trading program requires that the differences in impacts between activities be taken into consideration when trades are made. In Europe the so-called EMEP matrix demonstrates the interlinkages between each emitter and about 500 distinct deposition sites for sulphur wastes. This means, in effect, that any trade between emitters of sulphur must take into consideration the changed impacts of the location of emissions on all 500 distinct zones; in other words, a tradeable permit institution within this complex system would require the acquisition of 500 distinct deposition permits in order to substitute sulphur emissions at one site for another. The transactions costs of such a system renders trading infeasible.
Swanson and Mason (1996).

5.5.1 Water Banks
Part of the reluctance of authorities to use a free market in freshwater ecosystem transactions is based in the broad-based economic changes that this would imply. There are many primary and secondary effects that the permanent transfer of rights would have. For example, the shift of rights away from agriculture to industry is likely to have a pronounced impact on
the local economies of rural areas. Although it has been shown that at the state level, the secondary costs to the economy of water origin are not significant when compared to the benefits of improved efficiency, the costs will be borne by the local economy while the benefits accrue to the locality importing the water (Howe et al., 1990). Where water is transferred from agricultural to industrial use, it was shown in the US that ‘effects are exacerbated by the use of sales proceeds to repay heavy farm debt and the absence of local investment opportunity for these funds’ (Howe et al., 1990:1203). The political opposition to schemes that cause substantial economic restructuring provides frictions to resource reallocation.

By establishing a mechanism that transfers the right to freshwater ecosystem goods only temporarily, it is hoped that the secondary effects on the economic environment will be minimised. Water banking has been used in the US as a method of matching sellers with excess rights to buyers who can exchange the rights for a limited period of time. The case of the Californian water bank demonstrates this.

California has used water banks extensively in years of drought to reallocate rights to scarce water resources; organised by the Department of Water Resources, water is bought from farmers and then resold ‘to those who had the most critical needs’ (Kennedy, in Le-Moigne, 1992: 17). The efficiency of the system has improved over time as the state has gained experience in the mechanism. First established in 1976-1977, the Water Bank initially facilitated sales and purchases only from public entities, which limited the potential for distribution improvements. By 1991 the rules of transfer had been altered to include private users. Large volumes of water were reallocated, aided by the fact that a majority of the water in trade was from storage and so could be quickly and flexibly redistributed. This is indicative of the extent of the hoarding that existed prior to trading.

Supply did however outstrip demand; while a small amount was lost to the system, the remaining surplus was used for environmental projects and recharge (Dinar, 1997a: 24). Rules in subsequent years were altered so that a guarantee of purchase was received before the bank undertook to buy water from a supplier and demand was better matched with supply. Also, the supply of water from irrigated land put to fallow was prohibited to erase criticism that the water bank had a negative secondary effect on agricultural employment (Anderson and Hill, 1995: 87).

5.6 Pricing
5.6.1 Public Water Provision
As emphasised above, while the assignation of property rights over freshwater ecosystems determines the players in the game, they do not necessarily dictate the rules. One aspect of freshwater resource management is the determination of endowments (rights to resource rents) and a separate aspect is the determination of the management structure itself. Even though the issue of endowments must be determined, the issue of management is separable and many possibilities may be considered.

A common method for controlling the consumption of freshwater ecosystem goods is to assign its management to a central agency, frequently local or national government. In centralising the allocation decisions for the ecosystem, it is asserted that all externalities will be internalised and the public good aspects of freshwater systems provided.

Of course this is merely a restatement of the problem of management of large complex systems such as freshwater resources. The mere designation of a single agency does not necessarily mean that either the agency matches the range of the system perfectly, or that it has the instruments at hand to deal with the system. In actual fact, the assignation of ecosystem management to a body such as central government can create as many problems as it solves, a fact illustrated clearly by the case of the Aral Sea.

The Aral Sea in Russia was once larger than any of the Great Lakes (excluding Superior). The decision in 1918 to divert the two main tributaries of the lake, the Syr and Aru Darya, resulted in the lake shrinking in size by 66% (Holden, 1996). It left behind salinised soil that could not be used for agriculture and the local economies (traditionally based on fishing) were crippled with the loss of 60,000 jobs (Ellis, 1990). It is estimated that 35 million people were affected by the loss of the Aral, suffering health as well as economic problems as a result of the salt storms and saline soil.

The tragedy of the Aral resulted from the desire of a central government intent on producing cotton, or ‘white gold’, for export and thus to earn hard currency, at any cost. The local needs of the population were sacrificed for the good of the national economy. It took time for the true extent of ecological damage to become obvious; as the water level fell, the salinity of the soil rose and thus land required even more irrigation to be cultivated. A lack of awareness of local environmental needs by central decision makers stopped preventative action from being taken (Source: Ellis, 1990).

It would appear that in the case of freshwater ecosystems, one of the greatest difficulties for a centralised agency to overcome is the lack of local environmental and organisational knowledge. The extremely high number
of interactions between users in the case of freshwater ecosystems means that the side effects of any ecosystem management regime are wide ranging and reaching. Without detailed and specific knowledge of the ecosystem in question, a central body is at a disadvantage.

Additionally, the conflicting aims of central government may well prevent the economically optimal solution being reached. Only elected for a limited period of time, governments must curry political favour; any perceived shifts in the equity of the freshwater ecosystem goods allocation must be considered from a political as well as an economic perspective. As the number and heterogeneity of parties under the auspices of the authority increases, the smaller the changes must be to be accepted. These issues are demonstrated in the Latvian case of Daugavpils.

In order to improve water quality, the water utility of Daugavpils, Latvia attempted to reform its pricing policy to release capital for reinvestment in water supply. The primary concern of the water utility was that water would be affordable to households. The high level of unemployment, 10.6% in 1995 compared to the national average of 6.7% (Merrett, 1997:73), meant that it was considered inequitable to make the private installation of household meters compulsory. It also presented the utility with a restrictive affordability constraint; World Bank recommendations that prices should not exceed 3% per cent of average household income, allowed a maximum price per cubic metre water supplied of 9.5 santimes. This was less than total average costs and even less than the average operating costs, excluding the overhead costs and debt charges, of the water utility. So, despite aiming to achieve economic efficiency in water pricing, external factors prevented this (Source: Merrett, 1997 70-74).

The essential nature of freshwater ecosystems produces extreme reactions to alterations in the provision of its goods. In some cultures freshwater ecosystem goods are viewed as ‘gifts of god’ which should be provided free to all citizens. (Gleick, 1993) These factors combine to mean that state run utilities and government regulated franchises often subsidise the provision of freshwater ecosystem goods, charging a price that is less than its true economic value. The result is that consumers do not face realistic incentives when making their consumption decisions and are not motivated to improve the efficiency of use. The response of different groups in society to management systems also varies widely. The demand functions for freshwater ecosystem goods will vary depending on the uses and therefore it is common to set a different tariff for the agricultural, domestic and industrial sectors. The commercial demand for freshwater ecosystem goods has been found to be more elastic than residential demand, implying that a smaller change in price is necessary to affect commercial rather than
domestic consumption (Espey et al., 1997). Therefore governments concerned with the impacts on their various constituencies bring many other considerations into the management calculus.

All of these considerations indicate that the mere centralisation of the administration of freshwater systems does little to solve the problem of resource management. Sometimes these administrations introduce more complexities by virtue of the range of problems with which they are concerned (unemployment, growth) rather than bringing the necessary breadth to bear on the existing complexities within the natural system.

5.6.2 Marginal Cost Pricing
One pricing option that can improve the efficiency of use is to set prices based on marginal cost rather than the average cost of supply. By assigning prices to freshwater ecosystem goods equal to their marginal cost, the full benefit to society of those goods will be reflected in equilibrium. Users facing such prices will base consumption decisions on the real economic cost of providing the goods and so should reach the socially optimal level of consumption (Dinar, 1997a).

Although technically accurate, marginal cost pricing is hard to implement as it is usually very difficult to ascertain exactly where the marginal cost curves of society lie. Especially in trying to incorporate the scarcity value of the freshwater ecosystem, it is unlikely that authorities will be able to devote the time or money necessary to find the true marginal cost of provision (Dinar, 1997a). Additionally, the marginal cost varies over time; this means that prices would constantly need readjusting to take into account the seasonal cycle (available supply), and the level of demand. The case of Zimbabwe demonstrates how the cost of water can vary over time.

The cost of water supply varies with time depending on the kind of available technology, knowledge and experience of planners and implementers and also the time of use, e.g. seasonal farm use. Cost also depends on location, e.g. the construction of a dam or infrastructure for irrigation will require different amounts of expenditure depending on where it is and the area it must serve. Thus price determined by the marginal cost of supply will vary amongst regions and over time. The potential magnitude of this difference is illustrated in Zimbabwe, where ‘tariffs to farmers in the various provinces have varied from Z$9 per cubic metre to Z$278’ (Winpenny, 1994:9).

As mentioned above, equity issues are one of the primary concerns of government. It is possible that in a dry spell the marginal cost of provision would rise so much that it would become too expensive for lower income users to afford.
5.6.3 Average Cost Pricing
The use of marginal cost pricing by governments is limited - instead charges are more often based on average pricing combined with subsidies to promote equity issues. While the prices demanded do sometimes recover the costs of provision, it is rare that factors such as the external effects and the scarcity value will be taken into account. The consequence is that in many countries, consumers face a much lower price than necessary to achieve economic efficiency of allocation. Changes to regimes that are closer to opportunity cost pricing will always improve societal efficiency. This is demonstrated in the case of Indonesia.

Box 18: Bogor, Indonesia: elasticity of consumption
Even in developing countries, the liberalisation of prices will affect the consumption decisions of consumers. The removal of subsidies had a dramatic effect on the demand for water in Bogor; the water tariff was raised from US$0.15 to US$0.42 per cubic metre, resulting in a 30% decrease in the household demand for water. The higher price encouraged an increased efficiency in allocation combined with an aggregate fall in demand (Dinar, 1997a).

5.6.4 Dual Sector Water Pricing
In some countries such as Nigeria and Indonesia, the limited public sector infrastructure for the supply of freshwater ecosystem goods means that both the public and private sectors act independently to supply freshwater ecosystem goods. The result can be that too few goods are provided at an inefficiently high price to consumers, leaving suppliers to capture rents and exploit demand. The cases of Nigeria and Indonesia demonstrate this.

In Onitsha, Nigeria, while a number of homes were connected to the public water infrastructure, a majority of the population bought water from private water tankers, either storing the water for private use, or re-selling it as ‘small retail vendors’ to those unable to afford the capital outlay of storage facilities. In the dry season, the private sector supplied twice as much water as the public sector and yet it collected more than 23 times as much as the utility in revenues. Even in the wet season, the revenue collected by private vendors was 10 times higher than that of the public utility.
The price charged to consumers varied greatly depending on the supplier, as shown in the table below. This was partly due to the fact that private vendors, especially tanker drivers, were able to assert monopoly power by preventing entry into the supply market. It was also true that the water fee charged by the state water corporation was too low. Rent seeking by the private sector combined with insufficient public provision meant that ‘households in Onitsha were thus already paying water vendors over twice the operation and maintenance costs of the completed piped distribution system, and 70% of total annual costs’ (Whittington et al, 1991: 193).

<table>
<thead>
<tr>
<th></th>
<th>Rainy Season</th>
<th>Dry Season</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Private boreholes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) to tanker drivers</td>
<td>0.003</td>
<td>0.004</td>
</tr>
<tr>
<td>(b) to individuals</td>
<td>0.010</td>
<td>0.020</td>
</tr>
<tr>
<td><strong>Tanker trucks to individuals businesses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) per 1,000 gallons</td>
<td>0.014</td>
<td>0.018</td>
</tr>
<tr>
<td>(b) per drum</td>
<td>0.040</td>
<td>0.040</td>
</tr>
<tr>
<td><strong>Small retail water vendors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- to individuals</td>
<td>0.040</td>
<td>0.050</td>
</tr>
<tr>
<td><strong>Distributing vendors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- to individuals</td>
<td>0.120</td>
<td>0.130</td>
</tr>
</tbody>
</table>


Jakarta, Indonesia A similar system of water to supply to that in Onitsha is used in Jakarta, Indonesia. Here too the disparity in price paid to different suppliers is huge. Households purchasing from distributing vendors can pay as much as 50 times more than those connected to the public supply system. The deregulation of water supply was allowed in 1990, making the resale of water from private homes legal. This has the effect of increasing the number of points from which water is sold, thus reducing the distance over which consumers must carry water and increasing competition and limiting the room for rent seeking behaviour (Lovei and Whittington, 1991).

5.6.5 Decentralisation – Privatisation, Regulation and Representation

The privatisation of public utilities combined with close regulation by government aims to combine the need for profit maximisation by the individual supply firms with equity considerations enforced by the regulatory body. Such a system has been developed in England and France, at contrasting levels, with different degrees of success. In the end, some form of regulation and representation is necessary to ensure that the underrepresented uses and users (e.g. environmental goods and services) are provided for within a wholly private system.
In 1974, 10 regional water authorities were created in England and Wales, dealing with both water utility and river basin functions (Merrett, 1997). In 1989, the utility functions of the water providers were transferred to independently regulated private agencies, while the environmental functions, e.g. flood defence and pollution control, remained in the control of a public agency. This was based on the belief that the ‘environmental functions have to remain in the public sector, on clear principle, because they depend on regulation and enforcement (in legal terms), and because they involve the allocation of common natural resources and the provision of indivisible public goods (in economic terms)’ (Kinnersley, 1993: 29).

In the case of the UK, the benefits of privatising the water utilities were limited. Firstly, the main operational efficiency gains within the regional water authorities came before they were sold, in order to encourage the initial privatisation (Kinnersley, 1993). Secondly, ‘the backlog of capital spending and the EU’s environmental legislation necessitated a large capital-spending programme, driving up overhead costs and pushing the rate of increase in charges well above the inflation rate’ (Merrett, 1997: 138). In addition, the rationalisation of the utilities involved large scale job losses in a time of already high unemployment. Shareholders seemed to gain to a greater extent the consumer and the proportionate increase in salaries to directors was much higher than to other workers. As a result, the problems that privatisation had aimed to solve were replaced rather than eliminated (Kinnersley, 1993; Merrett, 1997).

Other forms of decentralised management involve the participation of users in the supply freshwater ecosystem goods at the local level. User Associations have been used extensively in Asia to ensure efficient allocation of water resources at the local level.

The WUA method of user participation was adopted in Sri Lanka to rehabilitate the Left Bank of the Gal Oya in the early 1980s. Communication between farmers and governmental officials was seen to greatly increase, and in addition co-operation between farmers themselves reduced the conflicts over water use. The clearing of a canal in one area allowed land which had previously been left fallow to be cultivated, benefiting over 300 families. This illustrates the positive effects that participation at the local level can have, highlighting the potential force of community concern for water management (Easter and Hearne, 1993: 7).

User Associations are particularly effective where the efficient allocation of freshwater ecosystem goods requires intra rather than inter-sectoral reallocation (Dinar, 1997a). Most examples of this system functioning
successfully involve a small or homogeneous parties, who stand to gain a
great deal from co-operation that is to the advantage of them all. It is rare
that user associations encompass all factions of society and in addition, the
close link between users and collective action means that equity issues are
likely to be given priority over economic efficiency. Where it is not possible
to undertake the optimal reallocation of rights and monitoring of the
situation, reallocation between sectors would need to be assigned to a higher
level of organisation.

The establishment of a user organisation provides a forum for the
encouragement of efficient use and a body through which the monitoring
and enforcement of use can be performed. Through the initial assignment of
rights to water and the introduction of community based management, a
solid basis for cooperation is built (Dinar 1997a, Easter and Hearne, 1993).

Privatisation of water resource management is capable of providing for the
efficient provision of the basic flow of services to the most prominent user
groups for the system, e.g. water consumption by individuals and industry.
The problems with privatisation of the management function arise from the
fact that the vast majority of the interactions within a freshwater system do
not fall within this functional classification. Uses for environmental
services, the support of other species and their habitats – all of these uses
must be provided by regulation after privatisation. To the extent that the
marginal value of water resources is highest in public rather than private
uses, then privatisation will tend to overlook these uses. The basic
management system must be developed in a manner that places these uses at
the core of its functioning, not as an add-on.

5.7 Conclusion – Addressing the Problems of Managing
Systems

This section has demonstrated the basic elements of a theoretical solution to
the problem of managing freshwater resource systems, and the range of
institutions currently in use. There is not a very close match between that
which is required for the management of freshwater systems, and that which
currently exists. There are ardent proponents of each of the various forms
of water resource management: tradeable permits; water pricing;
privatisation. However, it is not difficult to demonstrate in each context
how far from the ideal each management system lies. The complexities of
the natural system render simplistic solutions impracticable.

The solution to the problem of managing freshwater systems lies in the
continuing evolution of wide-ranging management institutions that are
resource-focused. Too often the complexity of the management task with
regard to the resource is compounded by including with it the complexity of managing the whole of the society that is dependent upon it. One of the key tasks of institutional development should be to maintain a focus on the set of problems that are inherent within freshwater resource management (functional relationships, opportunity costs, and optimal charges). It is not possible to manage the natural system effectively when it is confused with a large number of other social goals. It should be recognised that the freshwater system cannot be a social sink through which the costs of all other social problems are run.

Even with the elision of vast numbers of confounding issues, there remains a formidable amount of systemic complexity in the arena of freshwater resource management. Given this complexity, it will be necessary to gear institutional change to certain key objectives, such as representation and opportunity cost. Targeting first best institutions is not a real possibility, so the core factors in the resource misallocation problem must be targeted instead.

In the case of freshwater resources, the basic problem is the under-representation of many uses and user groups, and the failure to incorporate their opportunity costs within resource allocation decision making. Institutions should focus on mechanisms that value, register and internalise these opportunity costs into their decision making processes. (Swanson and Vighi 1998). This will imply valuing a wide range of currently under-represented uses (such as habitat, wildlife, recreation) and bringing these into the balance with those that have been historically over-represented (such as agricultural and industrial consumption).

Box 18: Representing and Valuing Uses – the Milan aquifer
The city of Milan has acquired its drinking water directly from an aquifer underlying the city for over one thousand years. Deriving from the nearby mountainous regions and flowing from the Po river catchment area, it has never required any treatment prior to consumption. In the past thirty years, intensive application of agricultural chemicals in the Po River valley has resulted in the contamination of this aquifer for the first time, and water treatment plants must be constructed. The people of Milan, when surveyed about the opportunity costs of the aquifer’s contamination, stated a value (for uncontaminated water) that was far in excess of the agronomical values achieved by application of the agricultural chemicals. The people of Milan had never been consulted about the application of these chemicals, and their opportunity costs had not been included in the calculation of the value of this indirect use of the aquifer.
6. Conclusions on Freshwater Systems Management

The fundamental conclusions of this paper are as follows:

**Foundational System**
- The freshwater ecosystem provides a flow of services that lies at the base of most, if not every, economic sectors and activities.
- In particular, the freshwater ecosystem provides a foundation for many public and collective goods (environmental goods, species habitats) that will not persist without a reserved allocation.
- The allocation of freshwater ecosystem services between these many sectors, goods and activities is fundamental to the determination of what continues to exist on the face of the earth.

**Complex System**
- The freshwater ecosystem generates a flow of services that interlinks a large number of uses and users (direct and indirect) of an extremely wide variety.
- The freshwater ecosystem is impacted by these uses in complicated manners in many cases, and the nature of the relationship between an economic activity and its impact on the system is not always readily apparent.
- The freshwater ecosystem crosses many and varied management boundaries, generating as much institutional complexity as it does natural and economic.

*The Freshwater System Management Problem*
- The management problem is to reallocate the flows of goods and services from freshwater ecosystems to their best uses from the societal perspective.
- The first-best solution to this problem would require 1) the understanding of the functional relationships between activities and impacts; 2) the recognition of the opportunity costs of marginal use of the system; and 3) the internalisation of this cost to each use and user.
- The accomplishment of these tasks in the simplest possible context (uniform uses and users) is costly and difficult – the accomplishment of this task in the context of this level of systemic complexity (natural and institutional) is impracticable.

Towards a Solution in the Management of Complex Systems
- The first step toward addressing this problem is to separate out the two facets of the freshwater system – its foundational status and its complexity. The management of the resource cannot address all of the
aspects arising out of its status as a foundational good. If this is not done, then all social problems (employment, growth, poverty, insurance) are being managed through this single resource. These other problems must be addressed via other instruments, because freshwater resource management is sufficiently complex without being tied to the resolution of all other social problems.

- The second step toward addressing this problem lies in the recognition that simplistic solutions are not appropriate. Property rights, tradeable permits, pricing, centralised regulation, privatisation – all of these solution concepts suffer from the same set of problems. The complexity of the interlinkages within the resource system implies that any single institution can only bring a portion of the total impacts between uses and users within its scope and coverage. Each system can act as the template for moving towards cooperation, but each is necessarily incomplete in its coverage.

- The third step toward addressing this problem is therefore to recognise that freshwater ecosystems have much more in common with networks than with commodities. For this reason, their management is likely to be best conceived within the framework of network management and regulation. This implies all the regulatory issues associated with network management: common carriers, rights of access, access pricing, network ownership and maintenance. If the system is seen to be an important asset in itself, then this will suggest much more complex forms of regulation than the commoditising of the water which flows through it. Water systems must be seen as social assets, and management systems must be developed to address the system rather than the commodity it carries.

- The fourth step toward addressing this problem is to recognise that first-best institutions cannot always be the target, and that the avoidance of egregious misallocations of resources might have to serve as a second best policy. For this reason it may be best to identify those uses that are underrepresented in current decision making, and which uses will be systematically undervalued, and then to channel resources toward these.

- The fifth step toward addressing this problem is to encourage freshwater system management as an opportunity for developing broader forms of cooperation and management, across systems, sectors and boundaries. It is natural systems such as these that make the evolution of social institutions possible, precisely because they make it necessary.
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Annex 1 Comments from Peer Reviewers

The peer reviewers of this document were

Gayatri Acharya, India
Axel Dourojeanni, Chile
Mihaela Popovici, Romania
Anonymous, Kenya

The comments by the peer reviewers ranged from issues of detail and clarification to broader issues of substance and approach. Due to time constraints the comments have not been integrated into a revised paper but are instead provided here in this annex as a supplement for stimulating discussion at the workshop planned for 9-11 June. It is intended that these and the comments and issues that arise out of the discussions in Bangkok will be integrated into a final version of the paper after the workshop. The comments are provided here as we receive them and the substance and approach issues arising out of the reviews have been integrated into the agenda of the workshop so as to frame the discussions at the workshop.

A1: Gayatri Acharya, India

This paper provides a background to the resource and management issues concerning freshwater ecosystems. As such, it identifies linkages between economic and hydrological systems and discusses theories of public goods and externalities as they relate to freshwater ecosystems. It discusses at length various strategies to address the problem of managing this resource, keeping in focus the specific nature of freshwater ecosystems.

The paper covers a number of issues in a clear and thorough manner. It focuses on practical approaches to managing complex resources and strikes a comfortable balance between theoretical proposals and real possibilities. However, precisely because the authors address so many issues, there is some unnecessary repetition which makes the paper longer than it needs to be. For example, the discussion of externalities could be combined and made shorter as could the references to the Coase theorem. My main criticism is essentially that the paper needs to be more concise since the issues it covers are complex and many.

A1.1 Sections

2.1.1: Freshwater ecosystems include a variety of environments such as rivers, lakes, marshes, swamps, canals and reservoirs. “Wetlands” is, in some ways, an even broader term, embracing saline water environments as well. Therefore, I think a definition of freshwater systems is required and if “wetlands” is to be used as a synonym then it should be stated as such.
2.1.2 : When discussing the private and/or public good nature of freshwater ecosystems, it should be noted that complex property rights regimes may exist within a single freshwater ecosystem.

I think it is also important to note that some quantity related aspects of these ecosystems may also be public goods but not pure public goods, since consumption of the good is affected to some extent, i.e., such resource use is considered non-exclusive but rival. However, biodiversity and non-use values are considered pure public goods.

Figure 2 and the related discussion suggests that quantity \( q_n \) is a function of the amount of water extracted but makes no mention of the stock of water available. In fact quantity of available freshwater = \( f (q_n, S_w) \) where \( S_w \) is the stock of water.

While the figure may be kept simple to make the point that the amount of available freshwater is a function of quantity and quality, the text should mention the effect of other losses and inflows to the stock of freshwater since these can significantly affect the interaction between the economic and hydrological systems (particularly in semi-arid areas where the flow of water in freshwater wetlands may be seasonal).

From the social welfare point of view, the maximisation of long run social benefits from the resource could be accomplished by the efficient allocation of the resource among competing uses in present and future periods. Resource allocation between uses is, however, also governed by the physical or hydrological state of the system.

Some of the discussion in section 5 (see below) really belongs in this section since it makes the important point that the ability of the freshwater ecosystem to function as a sink for wastes may be affected by the quantity of water remaining in the system. Furthermore, figure 6 (?) should be removed since it is the same as figure 2.

Minor points : Subscripts on q’s are not always showing up as such. Typographical error on page 8, last line of section 2.3, not now.

Section 3: Why are indirect services of freshwater ecosystems not included in the individual’s utility function? Economic activities may also depend on indirect services and some activities may impact indirect services. For example, increased withdrawal of surface water resource to irrigate sugarcane may affect groundwater recharge and consequently utility levels of the same or some other individual using groundwater.
The paragraph defining an externality can be omitted or converted to a footnote, particularly since externalities are again discussed in 3.1.1 and related back to these examples. This section can be made tighter.

Minor point: In the example of the impact of a negative externality on utility levels of individual A and B a multiplication sign is missing.

3.1.1 Minor points: Note that the terminology used for the figure differs slightly from the text. Since this paper has presumably been written to include non-economists, it is important to be consistent. Also, marginal external costs are not defined in the text.

The x representing the NE is not placed correctly – maybe use a different symbol altogether (a bullet perhaps?) or X.

3.2.1 There are also “departmental” boundaries. E.g., water resources within forested areas are not always under the jurisdiction of the water resource ministry or department. And the Forest Department may not be responsible for them either, particularly if these resources do not play an obvious role in forest maintenance or management (e.g., springs).

Table 3: It is not clear to me as to why “wetlands” are a quantity related societal use. Non-cultivated resources – grasses, fruits etc should also be included in the table.

Section 5: As previously mentioned, the first part of section 5.1 up to and including the discussion of opportunity costs should be in section 2.

5.5 (pg 46): These markets are also “thin” either because of geographical and/or pollutant restrictions or because of a reluctance to participate.

5.7 : I concur with the statement that the freshwater system cannot be a sink through which the costs of all other social problems are run. However, some social problems may in fact be better addressed by a resource-focused approach. For example, a resource-focused approach would require us to address issues such as uses, user groups, getting prices right etc., and would therefore have an impact on broader social and economic relations as well - a type of double dividend.
A2: Axel Dourojeanni, Chile

We believed that considerable improvement needs to be made to the document so as to be useful for the meetings. We are sorry not to be more positive at this stage knowing that little time is left.

A2.1 Introduction

Over the last decade, a series of changes have occurred in many countries of the world which have resulted in the reduction of the role of the state in the economy, including water resources management and use, and in the increased reliance on economic and market incentives in addition to -and in extreme cases, instead of- traditional methods of water management. The main trends include: the expansion of the private sector role in the provision of water-related goods and services (privatization) and a definite move towards the self-financing of water services, strengthening private property rights to water and using markets for water allocation, and using economic incentives rather than command and control measures for water pollution control.

Some of the many forces that encourage this changes are the increasing competition for water, in terms of both quantity and quality; the need to improve the economic and financial efficiency of the management of economic activities related to water use; a noticeable increase in the economic and financial losses from water-related natural disasters; and international agreements on environmental matters in general, and on water matters in particular.

These new trends in water management force a reconsideration and readjustment of the role of the state in water management. They demand not only that the state withdraw from many activities but, that it takes on many new ones, often of a very different nature and requiring different skills and knowledge of the public sector personnel. In water resources, all the experiences show that increased reliance on economic and market incentives requires continuing managerial actions by the public sector.

We would like to draw attention to two important concerns in respect of the recent changes in water management: (i) it is frequently ignored that strong regulatory and institutional arrangements are crucial to the success of market-based economic polities; and (ii) there is a tendency to favour this limited view of economic efficiency at the expense of other, at least equally important, aspects of water management, such as long-term environment sustainability, meaningful public participation, a comprehensive and multidisciplinary analysis, the need to integrate the so-called informal sector, etc.
A2.2 General
The time available for comments was very short. We received this paper on Friday and had to send comments on Monday. Had we had more time, our comments would have been much more detailed.

The title of the paper does not correspond to the issues discussed. The topic of economic security is not discussed at all. The discussion of conflict management (by the way, water management is the management of conflicts) is very weak.

The objectives which this paper pursues are not clear. The main conclusions of this paper are too obvious: (i) water resources management is a very complex task; (ii) any single method -from the very limited list discussed in the paper- cannot be relied upon in all situations and cannot solve all problems; (iii) participation of all stake holders is important; and (iv) the public goods aspects of the water ecosystem are the most unprotected element. It is not necessary to write more than 60 pages to come to these obvious conclusions. There are almost no useful proposals.

A more productive use of time and resources would be to analyze the instruments available to water resources managers (prices, planning, property rights, markets, regulation, etc.) and to explain: (i) how should they be designed and used, what are conditions/prerequisites for their successful application; (ii) in what situations and for what problems they are useful and to what extent, and what are their limitations; and (iii) what has been the experience of the countries where they have been used.

Some complex and essential issues are not discussed at all (natural monopoly, river basin management, and many of the issues which we point out in the introduction (see above)) while others are discussed only in part (property rights, privatization, water markets, etc.).

Confusion. There seems to be some confusion in this paper regarding (i) water management at the sectoral level (the management of demand) and at multisectoral level (management of supply); and (ii) management/pricing of water as a resource, management of infrastructure to provide water-related goods and services, and management of water-related externalities.

Sources. Many sources are inappropriate. For example, there many references to "The Economist" which is not a publication specialized in water-related issues. A good/standard source of information on internal renewable water resources (Table 1) is the World Resources Institute. Information on drinking water supply coverage (Table 2) is out of date.
Estimates for 1995 (at least) are already available. Is it not necessary to refer to a study just to say through how many countries a river flows (boxes 2 and 6); this is common knowledge. The selection of sources is also inappropriate. For example, Anderson is one of the leading proponents of the expanded role of markets for water allocation; his views should be balanced by those of other, more sceptical researchers.

National/international. The discussion of international (transboundary) issues should be separated from the discussion of water management at the national level.

Examples. They are excessive. Many, if not all, are too short to provide meaningful information to the readers who do not know the situation well. Some are clearly unrelated to the problems being discussed. There are few examples from Latin America, although there are many useful and interesting experiences in the region.

Text. If this paper is to be published, it should be edited and its English considerably improved.

A2.3 Specific

Items 2 and 3. This chapter will benefit from the discussion of the supply, demand, and other physical and economic characteristics of water that pose challenges for institutional design, particularly for using markets, property rights and prices to respond to changing supply and demand conditions, and give rise to market failures that must be addressed by institutions in order to ensure efficient resource allocation and use. Some of the most important of these characteristics are: mobility, variability and uncertainty in supply, indivisibility, diversity of uses, sequential use, interdependency among users, bulkiness, and conflicting cultural and social values.

The discussion of public and private goods is useful but, as most water activities fall somewhere along the continuum between private and public goods, it would be more appropriate to analyze them -to assess their degree of marketability- in terms of excludability and subtractability, distinguishing private, public, toll, and open access goods. It would also be useful to mention merit goods and club goods.

This chapter would benefit from the discussion of other types of market failures that are important in the provision of water-related goods and services: natural monopoly and externalities. The latter is addressed in other sections of the paper but the former is ignored.
To make the discussion more clear, one suggestion would be to begin by saying that the efficiency of the competitive market system is based upon certain conditions. Water is a natural resource whose physical nature, and that of the associated goods and services, violates a number of the conditions necessary for the economically efficient outcome. In water resource management there are many cases in which markets depart from the conditions necessary for a market system of resource allocation to function efficiently. In economic theory these divergences are known as market failures. And then to discuss, at least, (i) public and private goods, (ii) externalities, and (iii) natural monopolies, as well as the need for coordination.

In the discussion of boundaries (3.2.1.), it is surprising that the concept of river basin and river basin management is not discussed at all. Because water is a unitary resource, there is a close interdependence among all water uses in the same river basin and all of them are, to a certain extent, mutually interfering. The property of mutually interfering usage implies that withdrawal, consumption and return flows by one user are likely to affect the quality, quantity and timing of supply for other users downstream making all the uses of the water in a river basin interdependent. It is equally important to note that in a river basin setting, both positive and negative externalities usually have their effect in one direction only, propagating from water users in the upstream reaches to downstream water users. This unidirectional feature of water -only upstream users can have a positive or negative effect on the volume or quality of water downstream, but the downstream users cannot do the reverse- has a distributional dimension which means that the resolution of water conflicts through negotiation or mutual control of external effects that work reciprocally is generally ruled out. For these and other reasons, the river basin is an ideal unit of analysis to deal with the problem of most water-related externalities and it is generally assumed that most externalities are captured by analyzing the river basin as a single unit. This is why the concept of integrated river basin management and the idea of establishing some form of river basin administrative authority for water management are very attractive and have been proposed for many years.

4.1.3. "The essence of any ..." (p. 22). A group of users might, under certain conditions, have an incentive to come to an agreement on the optimal allocation of water resources from the accounting stance of that group, but not from that of the society as a whole.

4.2. (p. 24). "For instance, take the case of an aquifer that supplies water to a group of identical users who rely on it for identical uses. In the case where
all users are at the same point in the hydrological system, require the water for the same purpose and are under the same jurisdictional control, each faces identical incentives to co-operate". They also face an equally strong inventive not to cooperate.

4.2. (p. 25). "The institution must be made as complex as the system itself". The institutions should not (and cannot) be made as complex as the system itself; rather it should reflect and take into account the complexity of the system under its responsibility.

4.3.1. (p. 25). "One of the most common ...". It is important to note that most water-related externalities are unidirectional (see above).

4.3.3. "The type of use ...". It is important to explain that each use/user has very complex requirements for different but interdependent physical, biological and chemical attributes of streamflows which vary in time and space (volume extracted, quality, level, velocity, etc.).

4.4.1. (p. 33) and 5.6 (p. 49). The Aral Sea is not in Russia. The main reason for the decision to stimulate the production of cotton was import substitution, rather than the promotion of exports.

5.3. (p. 41). The list of desirable attributes of a water allocation system seems to be from Howe, Schurmeier and Shaw (1986). The complete list of the desirable characteristics for an ideal water allocation system is as follows: flexibility in the allocation of existing water supplies, security of tenure for established users, whether or not the user is confronted with the real opportunity cost of the resources available for his or her use, predictability of the outcome of the process, equatability and fairness, and the capacity to reflect public values.

5.4. (p. 42). It is important to discuss and to explain the complex nature of water rights. The mobility of water presents problems in the establishment, definition and enforcement of property rights, which are the essential foundation of any market allocation mechanism. One aspects of the problem is that water is almost never fully consumed by any particular user, rather it is typically used and reused by many and varied users as it flows from upper watershed to the sea. This means that water rights are almost never exclusive but overlapping.

5.4. (p. 42). "The careful and transparent ...". The needs to be a more balanced discussion of the beneficial use requirement. Its absence can have vary negative consequences as evidenced in the case of Chile, the only country, to our knowledge, where this requirement does not exist.
5.5. There are many references to a "free market". Can there be a "free market" for water rights (or transferable discharge permits)? Externalities are pervasive in water transfers. From the viewpoint of economic efficiency, water rights holders must face the full opportunity costs of their actions, so external effects should be accounted for in transfer decisions. If this is not the case, external costs will be borne by society as a whole. This means that to ensure that market transfers do indeed produce net social benefits, water marketing must be conducted in an institutional framework which causes the buyers and the sellers to take account of third party impacts; this means that most transfers of water rights must be regulated.

5.4. (p. 47). "The main cause of this inactivity has been the complex set of rules and regulations within the system". This is obvious. The question is whether and how these regulations can be simplified. It is equally important to note that there are good reasons (the complexity of the ecosystem) for the existence of these rules and regulations.

5.5.1. Water banks are a form of water marketing. Their discussion, even if justified, should be separated from the discussion of area-of-origin effects (nonuser benefits and costs) of water transfers. Again these effects are much more complex that presented in the text.

5.6.1. There seems to be some confusion in this chapter between pricing of water as a resources and charging for the provision of infrastructure for water-related services. One should clearly distinguish the following elements of cost of water: (i) the costs associated with the supply of water to a consumer (infrastructure provision (financing), operation and maintenance); (ii) opportunity cost of water associated with its alternate use as a resources; and (iii) externalities imposed upon others.

5.6.1. (p. 48). The title "public water provision" is confusing (does not correspond to the issues discussed in the chapter). When discussing property rights it is important to clarify that in most countries of the world, water users are rarely accorded property rights to the water itself, that is to say to the sources of surface water, such as rivers, lakes, etc., rather water rights are usufructuary in that water users are given rights to access and use such water only for withdrawal or instream uses.

5.6.1. (p. 49). "Additionally, the conflicting ...". One of the central question for public policy is what institution/forum should be used to collect and process information on and account for externalities associated with water allocation decisions. This important question is discussed in passing in this paragraph as well as elsewhere in the text. The discussion is very
incomplete. A good starting point is the following study: Susan Christopher Nunn and Helen M. Ingram (1988), "Information, the decision forum, and third-party effects in water transfers", Water Resources Research, Volume 24, April 1988, Number 4, pp. 473-480.

5.6.5. The discussion of privatization (private sector participation) is incomplete and very partial. The need for and the nature of regulation are not discussed at all. The relation between the privatization of infrastructure for the provision of water-related goods and services, on the one hand, and the management of water as a resources, on the other, is not discussed at all.

5.6.5. (p. 53). "Such a system has been developed in England and France, at contrasting levels, with different degrees of success". There are many other examples.

5.6.5. (p. 54). "Other forms of decentralised ...". Water user organizations exist in many regions of the world. There are many example is Latin America. However, they are rarely -if ever- responsible for resource allocation; their main objective is infrastructure operation and maintenance. In general the discussion of user organizations is very incomplete. What is the point of saying that "It is rare that user associations encompass all factions of society" (p. 55). It is not clear why "equity issues are likely to be given priority over economic efficiency". The nature of decisions taken by a water users organizations depends, among many other factors, on the voting procedures, on how decisions are made, and on how benefits and costs are distributed.

5.6.5. (p. 55). It is not explained why "Privatisation of water resource management is capable of providing for the efficient provision of the basic flow of services to the most prominent user groups for the system, e.g. water consumption by individuals and industry". For example, "in the case of the UK, the benefits of privatising the water utilities were limited" (p. 54). Again this is a very complex issue which should be discussed in more detail.

**A3: Mihaela Popovici, Romania**

It is a good paper, but needs better structure. It seems to me that were two different person and no correlation among them as there several repetition of ideas, text and of one figure.

This brings difficulties in identifying the real message of the paper and the link with economic security.
But still it is a crucial subject and they done a great effort. My congratulations to them.

2.1.1 A definition of freshwater ecosystem is needed; you started with wetlands, and then freshwater ecosystem.

2.1.1 Water is a finite and vulnerable resource, and a social and economic good; water can be a 'good' and/or a 'service'. Also, to include the most important use: water supply.

2.1.1 To add: option values; future direct and indirect use values; biodiversity; conserved habitats.

2.2.1 The main impact: reduced availability of water for different purposes due to the inappropriate reallocation among the users.

2.2.2 The main impact: increase in cost factors. Poor water quality needs more expensive treatment as pollution diversifies. The highly sophisticated treatment costs escalate rapidly and the water suppliers may be reluctant to pay the same price for raw water regardless of its quality. Moreover, generating safe drinking water from surface water requires a higher effort of monitoring and treatment technology. Many of the pollution control costs as well as the costs of environmental damages originating in an industrial unit are diffused throughout the economy over time. Most of the costs are eventually passed along to customers. The absence of an appropriated systems of cost recovery and user charges impedes the consumers as beneficiaries pay for the water services. To reduce the cost of waste treatment, both industries and municipalities should be given incentives to reduce their waste loads based on the 'polluter pays' principle

2.2.2 Please explain: what is remaining ecosystem or reformulate.

Figure 2 This is not always true. Also waste to be replaced by pollutants. Waste has a totally different meaning: refuse from households, nonhazardous solid wastes from industrial and commercial establishments, refuse from institutions (including nonpathogenic waste from hospitals), market waste, yard waste, and street sweepings, construction and demolition debris, etc. or you can make separation between supplied water and wastewater discharged.

2.2.2 Not clear formulation: pollution does not affect the availability, but water quality.

3.1 More clear - consumers preferences
3.1.1 Please consider that marginal opportunity cost = marginal production (or private) + marginal user (or depletion cost), and marginal environment (or external cost)

3.2.1 Maybe clarification of duties and responsibilities among various stakeholders should also be mentioned.

3.2.2 This is a repetition. Again, the expression waste is used inappropriately: waste are dumped in landfills, it is OK, but here you speak about wastewater being discharged. Suggestion: include perverse incentives of polluter to dilute the wastewater before discharging, to reduce concentration of pollutants and pay less for the tariffs or penalty

3.2.2 Policy failures occur when policies have PUI in place which have the secondary impact that they harm the environment. Perhaps the best examples of such 'policy failures' are offered by the former planned economies.

4.1.3 Maybe to mention the simultaneous uncertainty of both costs and benefits of the real life.

4.3 Define commons.

5. The strategies need to be described as mentioned in the title of the chapter. Subchapters 5.2-5.6 should be separately approached.

5. Maybe depletion of water quantity or flow, but not of services, maybe decrease of quality of the services.

5.2 True, but at least include cost-recovery concept.

6. Please better organise the conclusions to reflect: the elements of the freshwater ecosystem, alternatives to their management, conflict management and its solutions. Identify 1-2 of economic security issues not explicitly described in the whole paper.

**A4: Anonymous, Kenya**

This is a very long paper, and almost entirely indigestible. It is also written extremely badly. It gives the impression of something polished off in a very short period of time. A lot of it is quite spurious, and most is over-simplistic and over-generalised. I would have expected better from an “expert academic”. I’d recommend a total rewrite (Jim Winpenny?).
Section 2.1.1  This says nothing and doesn’t really explain any of the TEV concepts. It is a list. Some meaningful examples might help.

Section 2.1.2: This is completely confused. Especially the paragraph starting The public or private nature … Some explanation of incentives to back up his arguments. For example “markets provide economic incentives to individual decision-makers” - just what does this mean, and please qualify. Ditto “often market signals are garbled by non-market institutional structures such as property rights, … etc” - this is completely meaningless unless backed up with something clearer. Ditto “ensure that individuals are getting the right set of signals” - what signals? Traffic lights?

2.2.2 Untrue statement that the quality of freshwater determines its usefulness to both nature and society.

Section 3. Just what is the point of all these equations and graphs? They add nothing to the text. This whole section does not really address the (economic) problems. We need something much clearer, much more tied into the real world, and also taking account of issues such as politics, land use and biology/ecology.

Section 4. Again, some real world examples and problems. This section is extremely confused.

Section 5. Could we see some clear strategies proposed instead of this textbook waffle?

Conclusion - addressing the problems of managing systems. “This section has demonstrated the basic elements of a theoretical solution to the problem of managing freshwater systems …”. No it hasn’t. Also - why do we need a theoretical solution? Aren’t we addressing practicalities?

Boxes: nice geographical spread. There should be more of this, but linked in much more closely to the main text. Also some African examples OTHER than the Nile?

I had hoped for something that addressed real-world issues and gave real-world examples. This doesn’t. At the end of reading it I just thought … yes? …. and so what? … And that the author should learn to write properly. And that, somewhere, there should be a clear outline of issues raised and conclusions reached (which needs to be MUCH clearer than that which is in the paper).