# Introduction

*R. Quentin Grafton*

*Water is the classic common property resource. No one really owns the problem. Therefore, no one really owns the solution.* (Ban Ki-moon, Secretary-General of the United Nations, 6 February 2008)

## 1. Overview

This book is a collection of previously published journal articles on the economics of water resources. In total there are 95 articles that cover a vast range of topics, locations and methodologies compiled in two volumes:

Volume I
I Environmental and In-Stream Flows (10 articles)
II Environmental Valuation (7 articles)
III Water Pollution (6 articles)
IV Irrigation (9 articles)
V Groundwater Use and Management (10 articles)

Volume II
I Residential and Non-Residential Water Use (8 articles)
II Rights, Ownership and Efficiency (9 articles)
III Water Demand and Supply Studies (9 articles)
IV Water Pricing and Management (10 articles)
V Water Scarcity and Reliability (10 articles)
VI Water Supply and Demand in Poor Countries (7 articles)

Collectively the volumes include both much cited or 'classic' papers, survey articles and many applied and some theoretical papers. The volumes do not purport to be a complete set of articles on the economics of water resources as there are thousands of published papers in the sub-discipline. Thus, some excellent papers in well researched areas, especially 'Irrigation' and 'Groundwater Use and Management', have not been included so as to make room for equally worthy articles in important topics that have often been neglected in the economics literature such as 'Water Supply and Demand in Poor Countries'. The volumes also do not include any articles in press, chapters in books or the many good mimeographs, working papers and unpublished works that have appeared in the 'grey' literature. In addition, some articles could not be included because of copyright reasons.

The contributions in the two volumes cover almost all of the key issues on the economics of water resources in 11 topic areas. Fundamental to balancing needs of use and non-use of water is an estimate of the benefits of environmental and in-stream flows within river systems, and also the recreational and other values associated with water quality. Implementing such studies can be expensive and involves a number of different techniques in terms of both stated and revealed preference methods. A selection of different case studies and examples of how to apply non-market valuation techniques to valuing water for both water quantity and quality are provided in Parts I (Environmental and In-stream Flows) and II (Environmental Valuation) of Volume I. In Part III (Water Pollution) the issues of waste and discharge are addressed from both a theoretical and applied perspective. Irrigation is a major water consumer and the key challenges to its better use are examined in Part IV (Irrigation). In many parts of the world groundwater is the principal source of water, but extraction is frequently sub-optimal. The problems of governance, optimal extraction and misuses of groundwater are addressed in section V (Groundwater Use and Management).

Volume II provides important contributions to understanding and managing household or residential water use. Various demand case studies and analyses are provided in Part I (Residential and Non-residential Water use) while Part III (Water Demand and Supply Studies) includes methods to estimate residential demand. Part IV (Water Pricing and Management) provides a number of contributions on efficient water pricing. Important issues are whether privatization is desirable in terms of water delivery and the relative efficiency of different ownership structures. Both topics are addressed in Part II (Rights, Ownership and Efficiency). The 'big picture', such as overall water scarcity and its management implications, is covered by the contributions in Part V (Water Scarcity and Reliability). The often neglected economic issues of water demand and supply in poor countries, and where there is a great need for improved water management, are examined in Part VI (Water Supply and Demand in Poor Countries).

## 2. Water Matters

Water is of fundamental importance. It is a necessity of life in terms of direct consumption but is widely used in agriculture and industry, and also for recreation purposes and the disposal of wastes. Fresh water – in terms of both its availability and quality – is also of critical impact to all terrestrial ecosystems.

*Water Consumption*

Despite its importance water rarely receives the attention it deserves, at least in rich countries, except when there is too much (floods) or too little (droughts) available. Indeed, many people do not even know how much they pay for water which, by weight, is by far the most important natural resource we consume. In high income countries, such as Australia, the average household consumption per capita is 285 L per day (Australian Water Association 2007) or 104 kL or $M^3$ per year (see Table One for units of measurement and conversion from SI or metric units to the American Engineering System units).

Thus every Australian, on average, consumes within the household 104 tonnes of water – an amount that far exceeds per capita production of solid waste, fuel or food by households. Even on a global scale, water withdrawal by humans is substantial – it represents about 30 per cent of total accessible runoff (Lomborg 2001, p. 151) and is increasing as global water consumption rose over sixfold in the twentieth century (Wolff and Gleick 2002, p. 10).



*Table 1 Units of measurement for water*

| Symbol | Name | Comparison to Litre | Example |
|---|---|---|---|
| mL | millitre | 1/1000th L | one droplet |
| L | litre | same | large soft drink bottle |
| kL | kilolitre | 1 thousand L | approx. 6 oil barrels |
| ML | Megalitre | 1 million L | 20 backyard swimming pools |
| GL | Gigalitre | 1 thousand million L | 1/500th volume of Sydney Harbour |
| $km^3$ | cubic km | 1 million million L | 1/500th volume of Lake Erie |

*Notes:*
1. 1 gallon (Imperial) = 4.546 L
2. 1 gallon (US) = 3.785 L
3. 1 cubic foot = 28.32 L
4. 1 cubic yard = 764.6 L
5. 1 acre foot = 1233.49 L

The lack of attention about water, at least in rich countries, is because many people pay very little for it – it accounts for less than 1 per cent of household budgets in wealthy nations – and it is readily available 24 hours per day, 365 days a year. The contrast to poor countries is stark. The United Nations Development Programme (UNDP) estimates that there are over one billion people with inadequate access to water and over two billion who lack basic sanitation (UNDP 2006, p. 2). A cross-country comparison of per capita water withdrawals by sector (domestic, industry, and agriculture) is presented in Table 2. Huge differences exist because of geography (some places are much drier than others), size of the population and income (richer people can afford to access more water and treat it to a higher quality).

Table 2 indicates that Benin – a West African country – has one of the world's smallest estimated annual per capita withdrawals of water at 15 kL while the US withdrawals of 1600 kL are one of the highest. Thus, on average, every American uses (for all purposes including industry, agriculture and residential uses) more water in a week than does a resident of Benin in one year. Differences in water consumption are also reflected in terms of water quality. The Food and Agriculture Organization of the United Nations estimates that about 3800 children die every day – almost exclusively in poor countries – as a direct result of unsafe drinking water and lack of proper sanitation (FAO 2007). Despite these alarming statistics, water access has increased dramatically over the past few decades such that the proportion of those with access to potable water more than doubled between 1970 and 2000. If the targets of the Millennium Development Goals for 2015 are met then 1.5 billion more people will benefit from improved water supply (FAO 2006) although this will require investments of upwards of $US180 billion (Rijsberman 2004, p. 511).

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*Table 2 World water consumption*

| Region & Country | Year | Total freshwater withdrawal (km³/yr) | Per capita withdrawal (m³/p/yr) | Domestic use (%) | Industrial use (%) | Agricultural use (%) |
|---|---|---|---|---|---|---|
| *Africa* | | | | | | |
| Algeria | 2000 | 6.07 | 185 | 22 | 13 | 65 |
| Angola | 2000 | 0.35 | 22 | 23 | 17 | 60 |
| Benin | 2001 | 0.13 | 15 | 32 | 23 | 45 |
| Botswana | 2000 | 0.19 | 107 | 41 | 18 | 41 |
| Burkina Faso | 2000 | 0.80 | 60 | 13 | 1 | 86 |
| Burundi | 2000 | 0.29 | 38 | 17 | 6 | 77 |
| Cameroon | 2000 | 0.99 | 61 | 18 | 8 | 74 |
| Cape Verde | 2000 | 0.02 | 39 | 7 | 2 | 91 |
| Central African Republic | 2000 | 0.03 | 7 | 80 | 16 | 4 |
| Chad | 2000 | 0.23 | 24 | 17 | 0 | 83 |
| Comoros | 1999 | 0.01 | 13 | 48 | 5 | 47 |
| Congo, Democratic Republic (formerly Zaire) | 2000 | 0.36 | 6 | 53 | 17 | 31 |
| Congo, Republic of | 2000 | 0.03 | 8 | 59 | 29 | 12 |
| Cote D'Ivoire | 2000 | 0.93 | 51 | 24 | 12 | 65 |
| Djibouti | 2000 | 0.02 | 25 | 84 | 0 | 16 |
| Egypt | 2000 | 68.30 | 923 | 8 | 6 | 86 |
| Equatorial Guinea | 2000 | 0.11 | 220 | 83 | 16 | 1 |
| Eritrea | 2000 | 0.30 | 68 | 3 | 0 | 97 |
| Ethiopia | 2002 | 5.56 | 72 | 6 | 0 | 94 |
| Gabon | 2000 | 0.12 | 87 | 50 | 8 | 42 |
| Gambia | 2000 | 0.03 | 20 | 23 | 12 | 65 |
| Ghana | 2000 | 0.98 | 44 | 24 | 10 | 66 |
| Guinea | 2000 | 1.51 | 161 | 8 | 2 | 90 |
| Guinea-Bissau | 2000 | 0.18 | 113 | 13 | 5 | 82 |
| Kenya | 2000 | 1.58 | 46 | 30 | 6 | 64 |
| Lesotho | 2000 | 0.05 | 28 | 40 | 40 | 20 |
| Liberia | 2000 | 0.11 | 34 | 27 | 18 | 55 |
| Libya | 2000 | 4.27 | 730 | 14 | 3 | 83 |
| Madagascar | 2000 | 14.96 | 804 | 3 | 2 | 96 |
| Malawi | 2000 | 1.01 | 78 | 15 | 5 | 80 |
| Mali | 2000 | 6.55 | 484 | 9 | 1 | 90 |
| Mauritania | 2000 | 1.70 | 554 | 9 | 3 | 88 |
| Mauritius | 2000 | 0.61 | 488 | 25 | 14 | 60 |
| Morocco | 2000 | 12.60 | 400 | 10 | 3 | 87 |
| Mozambique | 2000 | 0.63 | 32 | 11 | 2 | 87 |
| Namibia | 2000 | 0.3 | 148 | 24 | 5 | 71 |



*Table 2 continued*

| Region & Country | Year | Total freshwater withdrawal (km³/yr) | Per capita withdrawal (m³/p/yr) | Domestic use (%) | Industrial use (%) | Agricultural use (%) |
|---|---|---|---|---|---|---|
| Niger | 2000 | 2.18 | 156 | 4 | 0 | 95 |
| Nigeria | 2000 | 8.01 | 61 | 21 | 10 | 69 |
| Rwanda | 2000 | 0.15 | 17 | 24 | 8 | 68 |
| Senegal | 2002 | 2.22 | 190 | 4 | 3 | 93 |
| Sierra Leone | 2000 | 0.38 | 69 | 5 | 3 | 92 |
| Somalia | 2000 | 3.29 | 400 | 0 | 0 | 100 |
| South Africa | 2000 | 12.50 | 264 | 31 | 6 | 63 |
| Sudan | 2000 | 37.32 | 1030 | 3 | 1 | 97 |
| Swaziland | 2000 | 1.04 | 1010 | 2 | 1 | 97 |
| Tanzania | 2000 | 5.18 | 135 | 10 | 0 | 89 |
| Togo | 2000 | 0.17 | 28 | 53 | 2 | 45 |
| Tunisia | 2000 | 2.64 | 261 | 14 | 4 | 82 |
| Uganda | 2002 | 0.30 | 10 | 43 | 17 | 40 |
| Zambia | 2000 | 1.74 | 149 | 17 | 7 | 76 |
| Zimbabwe | 2002 | 4.21 | 324 | 14 | 7 | 79 |
| *North and Central America* | | | | | | |
| Antigua and Barbuda | 1990 | 0.005 | 63 | 60 | 20 | 20 |
| Barbados | 2000 | 0.09 | 333 | 33 | 44 | 22 |
| Belize | 2000 | 0.15 | 556 | 7 | 73 | 20 |
| Canada | 1996 | 44.72 | 1386 | 20 | 69 | 12 |
| Costa Rica | 2000 | 2.68 | 619 | 29 | 17 | 53 |
| Cuba | 2000 | 8.20 | 728 | 19 | 12 | 69 |
| Dominica | 1996 | 0.02 | 213 | — | — | — |
| Dominican Republic | 2000 | 3.39 | 381 | 32 | 2 | 66 |
| El Salvador | 2000 | 1.28 | 186 | 25 | 16 | 59 |
| Guatemala | 2000 | 2.01 | 160 | 6 | 13 | 80 |
| Haiti | 2000 | 0.99 | 116 | 5 | 1 | 94 |
| Honduras | 2000 | 0.86 | 119 | 8 | 12 | 80 |
| Jamaica | 2000 | 0.41 | 155 | 34 | 17 | 49 |
| Mexico | 2000 | 78.22 | 731 | 17 | 5 | 77 |
| Nicaragua | 2000 | 1.30 | 237 | 15 | 2 | 83 |
| Panama | 2000 | 0.82 | 254 | 67 | 5 | 28 |
| St. Lucia | 1997 | 0.01 | 81 | — | — | — |
| St. Vincent and the Grenadines | 1995 | 0.01 | 83 | — | — | — |
| Trinidad and Tobago | 2000 | 0.31 | 237 | 68 | 26 | 6 |

*Table 2 continued*

| Region & Country | Year | Total freshwater withdrawal (km³/yr) | Per capita withdrawal (m³/p/yr) | Domestic use (%) | Industrial use (%) | Agricultural use (%) |
|---|---|---|---|---|---|---|
| United States of America | 2000 | 477.00 | 1600 | 13 | 46 | 41 |
| *South America* | | | | | | |
| Argentina | 2000 | 29.19 | 753 | 17 | 9 | 74 |
| Bolivia | 2000 | 1.44 | 157 | 13 | 7 | 81 |
| Brazil | 2000 | 59.30 | 318 | 20 | 18 | 62 |
| Chile | 2000 | 12.55 | 770 | 11 | 25 | 64 |
| Colombia | 2000 | 10.71 | 235 | 50 | 4 | 46 |
| Ecuador | 2000 | 16.98 | 1283 | 12 | 5 | 82 |
| Guyana | 2000 | 1.64 | 2187 | 2 | 1 | 98 |
| Paraguay | 2000 | 0.49 | 80 | 20 | 8 | 71 |
| Peru | 2000 | 20.13 | 720 | 8 | 10 | 82 |
| Suriname | 2000 | 0.67 | 1489 | 4 | 3 | 93 |
| Uruguay | 2000 | 3.15 | 910 | 2 | 1 | 96 |
| Venezuela | 2000 | 8.37 | 313 | 6 | 7 | 47 |
| *Asia* | | | | | | |
| Afghanistan | 2000 | 23.26 | 779 | 2 | 0 | 98 |
| Armenia | 2000 | 2.95 | 977 | 30 | 4 | 66 |
| Azerbaijan | 2000 | 17.25 | 2051 | 5 | 28 | 68 |
| Bahrain | 2000 | 0.30 | 411 | 40 | 3 | 57 |
| Bangladesh | 2000 | 79.40 | 560 | 3 | 1 | 96 |
| Bhutan | 2000 | 0.43 | 199 | 5 | 1 | 94 |
| Brunei | 1994 | 0.09 | 243 | nd | nd | nd |
| Cambodia | 2000 | 4.08 | 290 | 1 | 0 | 98 |
| China | 2000 | 549.76 | 415 | 7 | 26 | 68 |
| Cyprus | 2000 | 0.21 | 250 | 27 | 1 | 71 |
| Georgia | 2000 | 3.61 | 808 | 20 | 21 | 59 |
| India | 2000 | 645.84 | 585 | 8 | 5 | 86 |
| Indonesia | 2000 | 82.78 | 372 | 8 | 1 | 91 |
| Iran | 2000 | 72.88 | 1048 | 7 | 2 | 91 |
| Iraq | 2000 | 42.70 | 1482 | 3 | 5 | 92 |
| Israel | 2000 | 2.05 | 305 | 31 | 7 | 62 |
| Japan | 2000 | 88.43 | 690 | 20 | 18 | 62 |
| Jordan | 2000 | 1.01 | 177 | 21 | 4 | 75 |
| Kazakhstan | 2000 | 35.00 | 2360 | 2 | 17 | 82 |
| Korea Democratic People's Republic | 2000 | 9.02 | 401 | 20 | 25 | 55 |
| Korea Rep | 2000 | 18.59 | 389 | 36 | 16 | 48 |



*Table 2 continued*

| Region & Country | Year | Total freshwater withdrawal (km³/yr) | Per capita withdrawal (m³/p/yr) | Domestic use (%) | Industrial use (%) | Agricultural use (%) |
|---|---|---|---|---|---|---|
| Kuwait | 2000 | 0.44 | 164 | 45 | 2 | 52 |
| Kyrgyz Republic | 2000 | 10.08 | 1916 | 3 | 3 | 94 |
| Laos | 2000 | 3.00 | 507 | 4 | 6 | 90 |
| Lebanon | 2000 | 1.38 | 385 | 33 | 1 | 67 |
| Malaysia | 2000 | 9.02 | 356 | 17 | 21 | 62 |
| Maldives | 1987 | 0.003 | 9 | 98 | 2 | 0 |
| Mongolia | 2000 | 0.44 | 166 | 20 | 27 | 52 |
| Myanmar | 2000 | 33.23 | 658 | 1 | 1 | 98 |
| Nepal | 2000 | 10.18 | 375 | 3 | 1 | 96 |
| Oman | 2000 | 1.36 | 529 | 7 | 2 | 90 |
| Pakistan | 2000 | 169.39 | 1072 | 2 | 2 | 96 |
| Philippines | 2000 | 28.52 | 343 | 17 | 9 | 74 |
| Qatar | 2000 | 0.29 | 358 | 24 | 3 | 72 |
| Saudi Arabia | 2000 | 17.32 | 705 | 10 | 1 | 89 |
| Singapore | 1975 | 0.19 | 44 | 45 | 51 | 4 |
| Sri Lanka | 2000 | 12.61 | 608 | 2 | 2 | 95 |
| Syria | 2000 | 19.95 | 1048 | 3 | 2 | 95 |
| Tajikistan | 2000 | 11.96 | 1837 | 4 | 5 | 92 |
| Thailand | 2000 | 82.75 | 1288 | 2 | 2 | 95 |
| Turkey | 2001 | 39.78 | 544 | 15 | 11 | 74 |
| Turkmenistan | 2000 | 24.65 | 5104 | 2 | 1 | 98 |
| United Arab Emirates | 2000 | 2.30 | 511 | 23 | 9 | 68 |
| Uzbekistan | 2000 | 58.34 | 2194 | 5 | 2 | 93 |
| Vietnam | 2000 | 71.39 | 847 | 8 | 24 | 68 |
| Yemen | 2000 | 6.63 | 316 | 4 | 1 | 95 |
| *Europe* | | | | | | |
| Albania | 2000 | 1.71 | 546 | 27 | 11 | 62 |
| Austria | 1999 | 3.67 | 448 | 35 | 64 | 1 |
| Belarus | 2000 | 2.79 | 286 | 23 | 47 | 30 |
| Belgium | 1998 | 7.44 | 714 | 13 | 85 | 1 |
| Bosnia and Herzegovina | — | — | — | — | — | — |
| Bulgaria | 2003 | 6.92 | 895 | 3 | 78 | 19 |
| Croatia | | | | | | |
| Czech Republic | 2002 | 1.91 | 187 | 41 | 57 | 2 |
| Denmark | 2002 | 0.67 | 123 | 32 | 26 | 42 |
| Estonia | 2002 | 1.41 | 1060 | 56 | 39 | 5 |
| Finland | 1999 | 2.33 | 444 | 14 | 84 | 3 |

*Table 2 continued*

| Region & Country | Year | Total freshwater withdrawal (km³/yr) | Per capita withdrawal (m³/p/yr) | Domestic use (%) | Industrial use (%) | Agricultural use (%) |
|---|---|---|---|---|---|---|
| France | 2000 | 33.16 | 548 | 16 | 74 | 10 |
| Germany | 2001 | 38.01 | 460 | 12 | 68 | 20 |
| Greece | 1997 | 8.70 | 782 | 16 | 3 | 81 |
| Hungary | 2001 | 21.03 | 2082 | 9 | 59 | 32 |
| Iceland | 2003 | 0.17 | 567 | 34 | 66 | 0 |
| Ireland | 1994 | 1.18 | 284 | 23 | 77 | 0 |
| Italy | 1998 | 41.98 | 723 | 18 | 37 | 45 |
| Latvia | 2003 | 0.25 | 108 | 55 | 33 | 12 |
| Lithuania | 2003 | 3.33 | 971 | 78 | 15 | 7 |
| Luxembourg | 1999 | 0.06 | 121 | 42 | 45 | 13 |
| Macedonia | 2000 | 2.27 | 1118 | | | |
| Malta | 2000 | 0.02 | 50 | 74 | 1 | 25 |
| Moldova | 2000 | 2.31 | 549 | 10 | 58 | 33 |
| Netherlands | 2001 | 8.86 | 544 | 6 | 60 | 34 |
| Norway | 1996 | 2.40 | 519 | 23 | 67 | 10 |
| Poland | 2002 | 11.73 | 304 | 13 | 79 | 8 |
| Portugal | 1998 | 11.09 | 1056 | 10 | 12 | 78 |
| Romania | 2003 | 6.50 | 299 | 9 | 34 | 57 |
| Russian Federation | 2000 | 76.68 | 535 | 19 | 63 | 18 |
| Serbia and Montenegro | — | — | — | — | — | — |
| Slovakia | 2003 | 1.04 | 193 | | | |
| Slovenia | 2002 | 0.90 | 457 | | | |
| Spain | 2002 | 37.22 | 864 | 13 | 19 | 68 |
| Sweden | 2002 | 2.68 | 296 | 37 | 54 | 9 |
| Switzerland | 2002 | 2.52 | 348 | 24 | 74 | 2 |
| Ukraine | 2000 | 37.53 | 807 | 12 | 35 | 52 |
| United Kingdom | 1994 | 11.75 | 197 | 22 | 75 | 3 |
| *Oceania* | | | | | | |
| Australia | 2000 | 24.06 | 1193 | 15 | 10 | 75 |
| Fiji | 2000 | 0.07 | 82 | 14 | 14 | 71 |
| New Zealand | 2000 | 2.11 | 524 | 48 | 9 | 42 |
| Papua New Guinea | 1987 | 0.10 | 17 | 56 | 43 | 1 |
| Solomon Islands | 1987 | — | — | 40 | 20 | 40 |

*Source:* Pacific Institute (2007). Accessed http://www.worldwater.org/data.html February 19, 2008.



*Water Scarcity*

A growing world population expected to rise by another billion by 2050 (United Nations Population Division 2006), even under low growth forecasts, will exacerbate water shortages. Climate change will also have important impacts on water supplies (Mays 2007) and will make some dry areas even drier, such as South-east Australia (Jones *et al.* 2002), while increased evaporation and transpiration associated with higher temperatures will make it increasingly difficult to adapt to these changes. To the extent that climate becomes more variable with greater extremes of rainfall and temperature, existing chronic water shortages will likely become acute in low-rainfall periods. Apart from the difficulties to water users, this will impose increasing costs on the environment as consumption will almost certainly rise as a proportion of the amount of water available. An illustration of possible future trends is provided in Figure 1 which records river inflow and outflow and irrigation use on the Murrumbidgee River – a tributary of the Murray River – in South-east Australia over the period 1984–2005. Despite an overall cap since 1995 on total water use, the proportion of inflow diverted for agricultural purposes has increased dramatically in response to a more than 50 per cent decline in inflows from 1989 to 2005. As

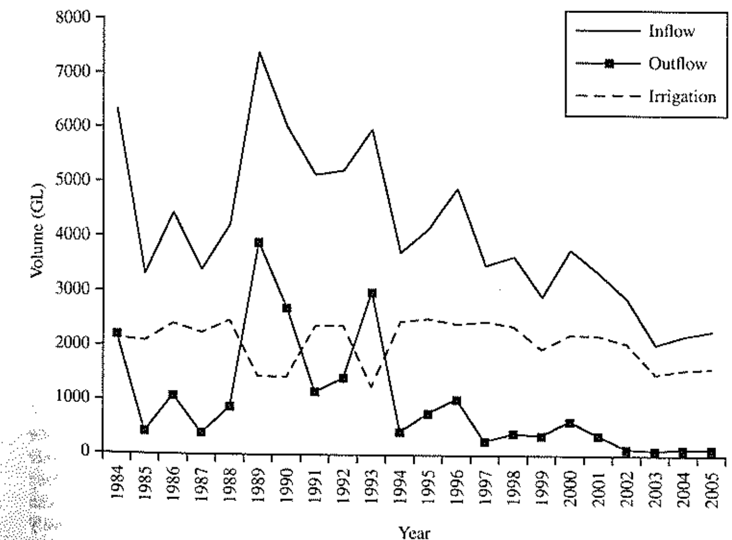



**Figure 1** *Annual inflow, outflow and irrigation use on the Murrumbidgee River, Australia 1984–2005.*

a consequence, in-stream flows as measured by outflows have become a fraction of previous levels.

Increasing population, higher temperatures, salt-water intrusion in coastal areas, and drying trends in some arid areas will place increasing strains on freshwater resources. Without a fundamental change in how water is managed scarcity problems will be made much worse. Part of the difficulty in managing water resources well is the nature of the resource. Water is mobile and to 'trap' and store it for future use can require substantial investments, especially for large capacity storage. Water, at least what comes from the sky, also does not belong to anyone until it is trapped on the ground with dams or underground in terms of aquifers. Acquiring 'ownership' of water, however, is expensive both in terms of infrastructure costs and the opportunity cost of the land allocated to water storage. Moreover, once stored, water depreciates through both evaporation and seepage even when consumption is zero.

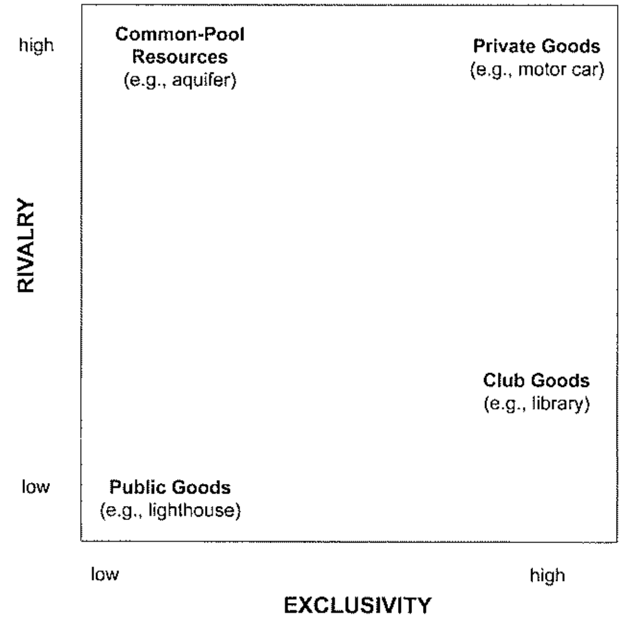
*Water Economics*

Water shares two characteristics that make it difficult for it to be used efficiently. First, many uses of water are rival in the sense its diversion for one activity reduces the amount available to others. For example, an irrigator may only return 20 per cent of the water that is diverted from a river, thereby reducing the amount available to downstream users. Some uses may also be rivalrous in terms of water quality. For example, the use of water and its subsequent discharge by a pulp and paper plant detracts from recreational uses of water, such as swimming. By itself, rivalry does not result in misuse or inefficiency. For example, many private goods are rivalrous in terms of consumption but are efficiently allocated through the market system. However, this requires that there are well-defined property rights over assets and persons without such rights can be easily and cheaply excluded from consuming what is not theirs. In the case of water, however, creating and enforcing user rights can be both difficult and expensive. These twin features – rivalry in use and difficulty in excluding people from accessing water that does not belong to them – means that water frequently has the characteristic of a common-pool resource. This is illustrated in Figure 2 with a comparison of the characteristics of a common-pool resource (aquifer) to private goods (car), public goods (lighthouse) and club goods (library).

Where water rights have been created, such as for surface water rights separated from land rights, they have generated substantial benefits to water users (Grafton and Peterson 2007). In turn, this has allowed water to trade to its highest value in use. However, to generate efficient outcomes holders of property rights must also have concomitant responsibilities or duties (Bromley 1991, chapter 2). In the case of water, such responsibilities include meeting water quality and return flow requirements. To achieve desired societal goals environmental allocations of water, such as minimum in-stream flow, may also be required.

Groundwater is a classic example of a common-pool resource. For instance, if an aquifer lies beneath many properties there are minimal incentives for a conservation-minded land owner to reduce pumping as the reduced water consumption will be diverted by someone else so long as the costs of delivering the water is less than the marginal value of what the water can generate. Consequently, and in the absence of effective collective action, an aquifer can easily be overexploited such that total withdrawals exceed recharge. A well-known example of overuse of groundwater resources is the huge Ogallala aquifer in mid-west and high plains of the USA (Rogers 1986) but overexploitation of large aquifers occurs in many places in the world.



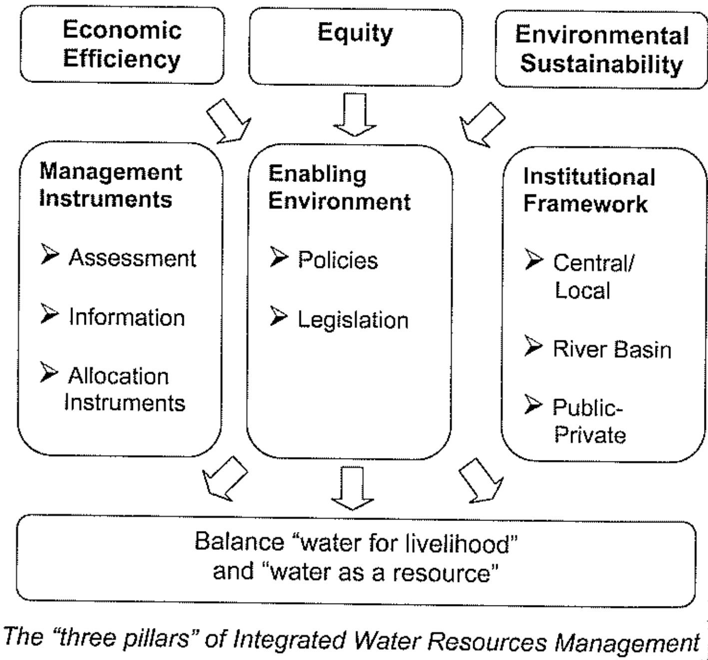



*Source:* Grafton *et al.* (2004), p. 37.

*Figure 2 Rivalry and exclusivity*

The pumping of aquifers in excess of recharge is particularly worrying because groundwater currently accounts for about 25–40 per cent of total freshwater use. Although not all aquifers are overexploited in a physical sense, the importance of groundwater consumption suggests that future total water availability will be less where overuse is currently occurring. As water scarcity increases, water conflicts will be exacerbated among users. Technical 'fixes' will help mitigate increased water scarcity and include water diversions from wetter to drier areas, and improved water conservation and water efficiency, especially in agriculture that accounts for about 70 per cent of global water use (Rijsberman 2004, p. 500). Such fixes, however, pose their own problems. Diverting water from one area or catchment to another is expensive and in many places of the world there are few locations where water is available without imposing substantial costs on users from where the water is being supplied, and also on the environment. On a micro-level, improved technical water efficiency that reduces seepage will also lower return flows and, thus, the amount of water available to other users and for the environment.

Improved water outcomes require water prices to reflect the value of water in use, and also non-use. In many parts of the world this will require a substantial increase in the price charged to users because many water consumers do not pay the full cost of water delivery and large subsidies are often provided to farmers in the form of below-cost pricing for water. These subsidies are very large and are estimated to be as much as $US60 billion per year globally (Brouwer and Pearce 2005, p.3). Higher per unit charges of water will encourage water conservation and efficiency and also investment to increase and improve existing supplies. Where equity concerns exist over higher water per unit prices, water suppliers can reduce fixed charges and governments can provide lump-sum assistance to consumers independent of household water consumption.




*Source*: FAO 2006, p. 26.

*Figure 3 Integrated water resources management*



*From Cheap Water to Dry Water*

The coming decades will see a fundamental shift in how water is managed. Business as usual will simply not be good enough to face the challenges of increasing water security. Simply put, the time of 'cheap water' is passing and the era of 'dry water' is upon us. As users and decision makers take up these challenges they will need an integrated approach to freshwater management – called Integrated Water Resource Management (IWRM) by the United Nations (FAO 2006) – that requires an interdisciplinary approach and a scope that goes beyond water management to include other natural resources such as land-use. This approach is illustrated in Figure 3.

One of the 'three pillars' of IWRM is economic efficiency. Many of the articles in these two volumes contribute to understanding how to improve economic efficiency in the management of water resources. Chapters in Volume I will help to achieve the second pillar of IWRM – environmental sustainability – by providing the methods to estimate non-use values of water and by showing how water managers can help achieve environmental goals. The many problems of misuse and overuse of water will be greatly mitigated if the insights compiled in these two volumes were to be more widely practised and understood. For too long the economics of water resources has not been given the attention it deserves.

In a world of increasing water scarcity the many insights the contributions in these two volumes offer about water pricing, optimal water use, trade-offs between use and non-use, water supply and demand and many other topics will be invaluable to ensure water continues to deliver the myriad of benefits we both expect and need.

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*Edited by*

R. Quentin Grafton

*Professor of Economics*
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