



**Thematic Week:** Water Economics and Financing

**Thematic Axis:** Water Markets

**Title:** Water Markets and Environmental Flows in Theory and in Practice

**Authors:** David Katz

Porter School for Environmental Studies, Tel Aviv University, Tel Aviv, Israel.

**Abstract:**

The practice of allocation of water for environmental objectives is increasingly common. In practice, often only minimum instream flow levels are required. This is rarely economically or ecologically optimal. Water markets offer an opportunity to advance beyond minimum flows and to achieve efficient allocations, with minimal political opposition. Markets in the western United States and Australia are already securing water for the environment. Experience, however, shows that environmental uses have difficulty competing against other consumers. This is due to their public goods nature, high transaction costs, and often a lack of marketable outputs. Governments, the largest purchasers of water for environmental purposes, are often obligated to purchase water by law. As such, the market functions more as a mechanism for compensation and least cost achievement of a legal mandate, and less as a vehicle for economically efficient allocation. The environment is also often affected by water market transfers between other consumers. Methods to minimize such third-party impacts include limiting the geographical scope of water transactions, restricting trade to consumptive use only, and dedicating a portion of water from all transactions to environmental objectives. Such restrictions minimize environmental impacts, but also limit the ability of the market to achieve efficient allocations.

**Keywords:** environmental flows, water markets, third-party impacts, law and economics

## **1. Introduction**

For much of the last century, in standard water allocation practices ecological water needs were often disregarded and ecosystems were left to make do with residual amounts of water left over after all offstream uses received allocations. Water left instream was often considered a waste of a resource. Such practices resulted in severe degradation of freshwater ecosystems, including the loss of over half of the world's wetlands (Finlayson and Davidson 1999) and nearly 30% of freshwater species (WWF 2006). With a growing understanding of the importance of water flow as a "master variable" in determining aquatic ecosystem functioning (Poff, Allan et al. 1997), however, scientists, economists, and policymakers are increasingly focusing attention on securing sufficient flows for ecological objectives (Petts 1996; Baron, Poff et al. 2002; Postel and Richter 2003).

The growing recognition of the value of allocation of water for environmental purposes is reflected in local and national laws, in international agreements, and even in the protocols and guidelines of international financial organizations.<sup>1</sup> Swiss water law, for instance, specifically specifies minimum flow quantities for rivers. South Africa's national water law goes even further, requiring that basic human needs and ecological needs receive priority allocations, and only water remaining after these two objectives are met is available for allocation for other purposes. Legal protection of water for ecological purposes is not restricted to water laws. In the United States, examples of legislation that have been perhaps the most effective in this respect include the Endangered Species Act, which requires protection of habitat for endangered and threatened species, and the Federal Power Act, which authorizes the Federal Energy Regulatory Commission to require supply of flows for environmental objectives as a condition for dam licensing or relicensing.

In terms of international law, the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (1997) lists environmental conservation as a criterion to be considered in the allocation of transboundary waters, and the Berlin Conference Report of 2004 – a summary of international water law – acknowledges the importance of environmental flows for ecological purposes. Numerous other international conventions and agreements also provide support for allocation of water for environmental objectives. International lending institutions such as the World Bank have also begun to consider aquatic ecosystem needs as part of their project evaluation criteria (Hirji and Panella 2003), and the World Commission on Dams (WCD) emphasized taking into account environmental needs in its recommended best practices for dam design and operation (King, Tharme et al. 1999).

One reason for the increased acceptance of allocation of water for environmental purposes is the realization that ecosystem services and other instream uses of water can provide significant economic benefits (Loomis 1987).<sup>2</sup> A study in the Western United States found the marginal value of water for recreational fishing to be higher than that for irrigation in 52 out of 67 watersheds observed (Hansen and Hallam 1991). Another study found that the ecological benefits of protecting Mono Lake in California exceeded the replacement cost of water from alternative sources by a factor of 50 (Loomis 1998). Ecological and social benefits from water in the Hadejia Jama'are floodplain in Nigeria were valued at \$9,600 to \$14,500 per cubic meter (in 1989-90 US dollars), compared to just \$26 to \$40 per cubic meter for upstream diversion of the water for irrigation (Barbier and Thompson 1998).

---

<sup>1</sup> For reviews of legal mechanisms and policies for provision of environmental flows see Dyson et al 2003, Scanlon and Iza 2004, or Katz 2006.

<sup>2</sup> For reviews of such economic studies primarily in the United States, see BoR 2001; NPS 2001; NPS 2004; Wilson and Carpenter 2004.

Given these potential and actual economic benefits, many economists have long advocated for use of markets in provision of water for ecosystem services (e.g., (Anderson and Johnson 1988; Colby 1990). Over the past two decades, water markets have indeed begun to play such a role, and this role can be expected to increase as water markets become more common and more sophisticated. Water markets have also had unintentional impacts on environmental flows, as water transactions between offstream users move water within and out of basins. This study will present a review of the theory and empirical literature addressing water markets and the environment. It will address both the use of markets to acquire flows for environmental purposes as well as the potential impact on the environment of water market transactions between other sectors, so called third party impacts. The study will highlight opportunities for increasing allocations to the environment as well as the numerous challenges involved.

## **2. Economic Approaches to Allocating Environmental Flows**

Much of the existing economic literature fails to differentiate between instream flows and environmental flows, a distinction increasingly made in the scientific literature. Instream flows are all waters left in a stream, river, or wetland. Environmental flows are waters left in a stream, river, or wetland that provide for ecosystem functions. Thus, environmental flows represent only a subset of instream flows. Instream flows for hydropower production, navigation, and recreation may or may not benefit aquatic ecosystems, which thrive under a natural flow regime and may not be able to function under a highly altered one. Thus, not only is the amount of water left instream important for provision of ecosystem services, but also the timing and quality of this water. This review addresses environmental flows, recognizing that instream flows for other purposes may also contribute to ecological functioning.

Water allocation to nature is generally included in economic models in one or a combination of the following three ways<sup>3</sup>:

1. *Environmental Externality*. Water is allocated to non-environmental sectors only. The environment receives whatever water is leftover, if any, after allocation to these sectors. Damage to the environment affects overall utility, but is not included in the objective function, as represented in Equation 1.

$$Eq. (1) \text{ Max } U(w_1, w_2, \dots, w_i) \text{ s.t. } \sum w_i \leq W_T ; \text{ but actual } U(w_1, w_2, \dots, w_i, w_e)$$

Where  $U$  = utility

$w$  = quantity of water allocated to sector  $i$

$i$  = water consuming sectors other than the environment

$W_T$  = total amount of water available for allocation to all purposes

$w_e$  = quantity of water allocated to the environment

In this case, utility for the purposes of the maximization problem is restricted to non-environmental sectors, but actual utility is a function of water for environmental purposes as well.

---

<sup>3</sup> Other methods have been proposed, but are less used in practice. For instance, Tisdell (2001) presents the option of “minimizing the average sum of squared differences between the actual and natural flow regimes, subject to the extractive use of water and available water for environmental use” (p. 116).

2. *Minimum Flows*. Maximizing utility from allocation of water to non-environmental sectors, subject to an overall water constraint and an environmental constraint. Such a method is represented by Equation 2.

$$Eq. (2) \text{ Max } U(w_1, w_2, \dots, w_i) \text{ s.t. } \sum w_i + w_e \leq W_T \text{ and s.t. } w_e \geq E$$

Where the notation is the same as above with the addition of:

E = some minimum flow requirement for environmental purposes

3. *Competitive Market*. Maximizing utility from allocation of water to all sectors including the environment, as represented by Equation 3.

$$Eq. (3) \text{ Max } U(w_1, w_2, \dots, w_i, w_e) \text{ s.t. } \sum w_i + w_e \leq W_T$$

The type of objective function used will depend in large part on the perceptions of the modeler and on the regulatory regime in place.

#### Environmental Externalities

The first model is common in cases in which no regulation exists for protection of environmental flows and markets do not exist which can provide for such flows. Such models, which do not explicitly incorporate environmental values in their objective function, have dominated water allocation models in the past, especially in areas in which water for nature was considered a waste of resources, or more commonly, was simply not considered at all. The result has been high levels of environmental degradation and in many cases, highly inefficient allocations.

#### Minimum Flow Allocations

The second type of model is common in regulatory regimes with minimum flow requirements. In regions in which water fully appropriated (and sometimes even in cases in which it is not), the result of such an approach is generally that the environmental flow constraint is binding, and thus, the environment receives only the minimum flow required by law. This amount is rarely ecologically or economically efficient.

Early scientific attempts to define minimum water requirements for ecological purposes used rules of thumb that related to channel size or average flow rates.<sup>4</sup> One of the most popular methods in practice has been the Tennant Method, which proposes a percentage of natural flow necessary to preserve different levels of quality in streams (Tennant 1976). The popularity of these types of methods is due in no small part to the ease and low cost of calculation. They are now, however, widely recognized as insufficient to preserve ecological functions (IFC 2002). Other methods, such as the Instream Flow Incremental Methodology (IFIM), determine actual water needs of specific species (Stalnaker, Lamb et al. 1995). Such methods generally take years of research and significant budgets to complete, making them less popular as policy tools. They are generally appropriate when the status of a specific species is important, such as preserving a threatened or endangered species, or promoting a valuable game species. Optimizing flows for one species, however, does not optimize flows for the ecosystem as a whole, and so such flow recommendations also may be ecologically sub-optimal.

Ecosystems depend on variation in streamflows in order, for instance, to scour channels, provide access to habitat and protected areas for various species, indicate spawning times, and

---

<sup>4</sup> For reviews of methodologies for determining environmental flow needs, see IFC 2002 or Tharme 2003.

disperse seeds along shore banks. Richter et al (1996, 1997) highlighted five hydrological characteristics important for ecosystem functioning: magnitude, frequency, timing, duration, and rate of change of hydrologic conditions. Most minimum flow regulations address only the magnitude of water, and some the timing (for instance requiring minimum flows only in the dry season). Rarely, however, do they address the full range of ecosystem water needs. As such, such an approach is far from optimal from an ecological perspective. As a burgeoning literature on the economic value of aquatic ecosystems is proving, minimum flow regulations are also often not economically efficient. Efficient allocations for environmental flows are often orders of magnitude larger than those required by minimum flow requirements (Loomis 1987; 1998).

#### Competitive Market Allocations

The second method for allocating water described above allocates economically efficient environmental flows. As priority water rights in many regions have been claimed by offstream uses, allocating water for environmental flows often requires reallocation. Several obstacles to such a reallocation by central water authorities exist, two of which are discussed herein. First, such reallocation is likely to be opposed by existing users unless they receive adequate compensation, and so strong lobbies may form in opposition (Gillilan and Brown 1997). Secondly, administrators often lack knowledge regarding marginal benefits of environmental flows, and thus, cannot determine what the shadow price of water is.

Markets can potentially address both concerns. Because they depend on voluntary transactions, sellers are compensated for their loss of water, reducing opposition. In addition, use of a decentralized market mechanism to reallocate water obviates the need for a central allocator to know marginal values of water in various sectors. In a fully functioning market, the shadow price will be revealed as the going market price. Furthermore, to the extent that water left instream for environmental purposes is available for offstream use further downstream, this can reduce the net costs of environmental flow acquisition. Thus, markets represent a potentially powerful tool for acquiring environmental flows.

Numerous challenges to efficient market allocation of environmental flows exist, however, some stemming from regulatory constraints, some from lack of scientific knowledge, and others from economic theory itself. Not all legal regimes allow for market transfers of water rights. In many countries and regions, water rights are tied to land rights or are fully owned by the government and cannot be sold or leased. In some cases, even when transactions are allowed and potentially efficient, they do not take place (Young 1986; Wilkenson 2008). One explanation for the lack of market activity is that owners may fear that lease of water rights would indicate that the initial allocation of water rights was inefficient, and thus, jeopardize their rights in the long term (Howitt and Hansen 2005).

Another significant obstacle to effective markets for environmental flows stems from the fact that they are primarily public goods. Thus, economic theory predicts that they will be underprovided, as some beneficiaries free-ride off the provision of others. In some legal systems, only the government is allowed to hold instream water rights. This monopsony position limits the effectiveness of the market. In legal systems in which private parties can purchase water rights, coordination among multiple beneficiaries can result in high transaction costs that limit market effectiveness.

A practical limitation that stems from environmental flows public good nature is that their economic value does not necessarily translate into financial value. Because the consumer surplus provided by environmental flows does not generate revenue streams the way that most offstream uses do, parties acting on behalf of the environment can find it difficult to compete successfully in the marketplace. Even in cases in which official water management agencies are involved in

market acquisitions of water, there is evidence that some such bodies view “economic values without cash transactions... as ‘second-class’ values” (Loomis et al 2003).

In order to determine the efficient amount of water to allocate to environmental flows, it is necessary to tie flow levels to ecosystem services, which are can then be valued in the market place. While the level of scientific understanding regarding the benefits of environmental flows has been increasing rapidly over the past years, it is still in its infancy. Several knowledge gaps exist in this realm. Most research on flows and ecosystem functioning, for instance, has looked at flows necessary for *maintaining* ecosystem services. These may differ substantially from flows necessary to *restore* ecosystem services, and it is often in arid areas, with degraded streams that the marginal value of water for the environment is highest (Gillilan and Brown 1997), and most able to compete in a market. For these reasons, many environmental flow recommendations are for allocating flows experimentally and allowing for readjustment, according to an adaptive management framework. Large scale experiments with water releases for environmental purposes along the Colorado River in the United States, for instance, have only partially achieved their designated goals, and have been twice revised since the first release. Without reliable information regarding the ecological and environmental benefits of environmental flows, economists cannot produce reliable estimates of economic values of such flows. In this sense, incorporating environmental flows into economic models is much more problematic than incorporating other instream flow goals such as promoting recreation or navigation, which can be estimated more easily and reliably.

In addition to the direct role markets can have in supplying environmental flows, they can also effect environmental flow levels via third party impacts resulting from trade between other right holders. These impacts may be positive or negative, depending on whether the transfers are upstream or downstream, and on the manner and timing of the transfers. The current transfer of water from Imperial Valley to San Diego and Coachella in California, for instance, is likely to reduce flow to the Salton Sea by up to 40%, threatening numerous species that use the inland lake for habitat and food (Cohen 2007). Models of efficient market allocation of the Colorado River, however, show that the result would be less water taken by upstream states and more transferred downstream, which would be potentially beneficial for the environment (Booker and Young 1994).

The provision of environmental flows through markets can itself have both positive and negative third party impacts. The provision of instream flows can benefit not only the environment, but also other downstream users. Ward and Booker (2003) show that the provision of water for preservation of an endangered fish species in the Rio Grande River, would result in net economic benefits for both the United States and Mexico. Market acquisition of environmental flows can also have negative social impacts on community members in the selling region, however; and can even have negative environmental impacts, if, for instance, selling of surface water rights results in increased groundwater pumping in the selling region. This is likely to occur in areas in which surface and groundwater rights are administered separately, a not uncommon situation in many countries. Furthermore, the public good environmental benefits from agriculture, such as terrestrial habitat provision and preservation of open spaces, may be harmed as water is traded away.

In sum, in places in which they exist markets offer an important option for provision of water for environmental objectives. Several factors, however, serve to limit and/or detract from the effectiveness of markets for these purposes. These obstacles include regulatory restrictions, thin markets, high transaction costs, limited information, and third party impacts.

### **3. Markets and Environmental Flows in Practice**

Growing experience with both water markets and environmental flow acquisition over the past two decades provides an opportunity to compare empirical evidence to the theoretical issues outlined above. Before providing such a review, it should be noted that the majority of such evidence reported in the English language literature focuses on experiences from a limited number of regions. The overwhelming amount of literature is limited to the Western United States, Australia, and, to a lesser extent, South Africa. Reasons for this include obvious language bias, as well as the fact that water markets are not widely in use. In other regions which do have active water markets, the environmental impacts of such markets seem not to have been well studied.<sup>5</sup>

Options for market-based water acquisition include purchase of water rights, short- and long-term leases, and dry-year options, according to which obligate right holders are paid to provide water in low rainfall years only. Landry (1998) reported that between 1990 and 1997, 2 million acre-feet of water was leased through markets and 132,000 acre-feet purchased for environmental protection. Several more recent studies have examined the functioning of water markets in the American West, including their relevance to environmental objectives (e.g., Loomis et al. 2003; Brookshire et al. 2004; Howitt and Hansen 2005; Brown 2006; Brewer et al 2008). They show that the market for environmental flows has grown significantly in recent years (Howitt and Hansen 2005). According to Brewer et al (2008), between 1987 and 2005 the total the amount of water acquired for environmental purposes through markets in the United States was over 7 million acre-feet in terms of annual flow and over 31 million acre-feet committed. Markets are becoming an important mechanism for acquisition of water for environmental flows in Australia as well. In 2008, the Australian government allocated \$3 billion (Australian dollars) out of its \$12.9 billion water budget to buy water from irrigators in the Murray-Darling Basin for environmental purposes over the next 10 years (Wilkinson 2008).

Several studies confirmed that the majority of market transfers are from agriculture to urban uses. Environmental purchases accounted for 9% of overall United States water market transactions between 1987 and 2005, but for 23% of the volume of the annual flow and 22% of the water committed (Brewer et al 2008). Agriculture was also the primary source of water sold for environmental objectives, accounting for roughly 80% of such transactions. These objectives included preservation of threatened and endangered species, commercial and game fish, other wildlife, water quality, wetland habitat, recreation options, and various other ecosystem services (Loomis et al 2003). In certain states, for instance, the Pacific Northwest with its commercially important salmon stocks, environmental purposes accounted for the majority of transfers (Howitt and Hansen 2005).

Prices paid for water for environmental flows in the United States tended to be lower than those paid by municipalities and irrigation (Brown 2006). This may support the contention discussed above that the public good status of environmental flows and the transaction costs associated with their purchase may mean that they are underprovided by open markets. Overall, the prices paid for environmental water in sales and leases in the U.S. markets, did tend to conform with the estimates of for such services using various nonmarket economic valuation methods (ibid 2006), thus adding credibility to the use of such methods in policy planning. Leases of water for environmental purposes have been more common than sales (Brown 2006), but offer less long term security. Because water is often most needed for environmental purposes during dry years, when the lease prices are high, many advocates for market acquisitions of environmental flows have pointed to option contracts as a method for lowering costs (e.g., Hafi et al 2005).

---

<sup>5</sup> For such a claim regarding Chile's water market, see Bauer 2004.

Several water trusts – organizations specifically dedicated to raising money for purchase of water for environmental purposes – have been established in recent years. Together with other environmental organizations, they have taken an active role in purchasing and leasing water rights for environmental flow objectives. Despite the potential of such private provision of public goods, however, in both the United States and Australia, two of the most developed water markets, the government remains by far the largest purchaser of water rights for the environment. In many cases, the environmental flow levels are required by regulation, and the market simply serves as a vehicle for efficient acquisition. In some cases, such as the Central Valley Project Improvement Act in California, in order to generate the funds necessary for water acquisition, a fee is added to offstream water use. In sum, it seems clear that however popular water markets become, the government will have an important role both in providing a regulatory framework supporting environmental flows and in actual acquisition of such rights.

The overwhelming majority of water market transfers are between agriculture and municipalities, or between agricultural users themselves. Because costs for pumping uphill are often prohibitive, much of the market transfers are from upstream to downstream users (e.g., Nieuwoudt and Armitage 2004). This can have net benefits for the environment. Still, many out of basin transfers and transfers of water via constructed infrastructure rather than via instream flow, meant that environmental impacts from water market transactions can be substantial (Tisdell 2001). Moreover, as Howitt and Hansen (2005) note, “externalities and third-party damages are likely to become more important as a greater volume is traded” (p.61).

Various regulatory mechanisms exist to limit the third party environmental damage from such transactions. In South Africa, the national Water Act ensures that environmental and human water needs are protected and cannot be harmed by transfers (Nieuwoudt and Armitage 2004). This limitation, along with the cost of determining what environmental water needs are, have likely contributed to the slow development of water markets in South Africa.

In the United States, some markets have been limited to have been limited to trade in consumptive use only, in order to protect return flows. Water rights, however, are traditionally for withdrawals, and calculation of consumptive use levels can add significantly to the transaction costs of market transfers (Brewer et al 2008). In many areas, transactions are limited to within watershed trades. In both cases, these limitations reduce environmental impact, but at the expense of restricting the cost-saving potential of the market and overall market activity. Given both the potential third party impacts and the lack of direct financial income from many forms of environmental flows, some states have imposed a tax on water market transfers. This tax can be in the form of a financial transaction fee, or, as is the case in Oregon and parts of California, a requirement that a certain percentage of water transacted be dedicated to environmental flows (McKinney and Taylor 1988; Howitt and Hansen 2005). Again, such requirements may provide for environmental flows, but at the expense of market efficiency.

#### **4. Conclusion**

The increasing recognition of the importance of environmental flows can be seen in the type and amount of regulations, legislation, and international agreements addressing the issue. Numerous economic valuation studies show that the public increasing values environmental flows and the amenities they provide. Given this economic value, water markets represent a potentially significant option for securing water for these flows. Existing water markets are already serving this purpose and this trend is on the increase. The provision of water for environmental objectives via markets is still largely determined by government regulation, and often results only in provision of minimum flows, which is rarely either ecologically or economically optimal. Despite the growing contribution of markets to securing water for the environment free markets alone are

unlikely to provide efficient amounts of environmental flows, given their public good aspect and high transaction costs associated with provision, inter alia. Thus, even with active markets, government will need to play a primary role both in providing a regulatory framework that values the environment as well as in actual provision.

The current state of knowledge about water markets and the environment is dominated by the experience of the United States and Australia. More research needed on other areas, especially those with long standing water markets, such as Chile and Mexico. Furthermore, much of the existing research on this topic addresses direct purchase and leasing of water for environmental purposes. While third party environmental impacts of water markets have long been recognized as potential and actual concerns, most of the literature on this topic has been anecdotal or case study in nature. Little systematic studies on this topic have been published. As environmental flows grow in importance and water markets increase in popularity, if such water markets are to truly benefit the environment, it is imperative to have a broad body of empirical research on which to refine policy.

### **Works Cited**

- Anderson, T. L. and R. N. Johnson (1988). "The problem of instream flow." Economic Inquiry 24: 535-554.
- Barbier, E. B. and J. R. Thompson (1998). "The value of water: Floodplain versus large-scale irrigation benefits in Northern Nigeria " Ambio 27: 434-440.
- Baron, J. S., N. L. Poff, et al. (2002). "Meeting Ecological and Societal Needs for Freshwater." Ecological Applications 12(5): 1247-1260.
- Bauer, C. J. (2004). "Results of Chilean water markets: Empirical research since 1990." Water Resources Research 40.
- Booker, J. F. and R. A. Young (1994). "Modeling Intrastate and Interstate Markets for Colorado River Water Resources." Journal of Environmental Economics and Management 26(1). (BoR), Bureau of Reclamation (2001). Economic nonmarket valuation of instream flows. D. o. t. Interior. Denver, CO, Bureau of Reclamation (BoR).
- Brewer, J., R. Glennon, et al. (2008). "Water markets in the West: prices, trading, and contractual forms." Economic Inquiry 46(2): 91-112.
- Brookshire, D. S., B. Colby, et al. (2004). "Market prices for water in the semiarid West of the United States." Water Resources Research 40.
- Brown, T. C. (2006). "Trends in water market activity and price in the western United States." Water Resources Research 42.
- Cohen, M. (2007). "Salton Sea at a Crossroads." GeoTimes August.
- Colby, B. G. (1990). "Enhancing instream flows in an era of water marketing." Water Resources Research 26(6): 1113-1120.
- Dyson, M., G. Bergkamp, et al. (2003). Flow: The Essentials of Environmental Flows. Gland, Switzerland, IUCN: 118.
- Finlayson, C. and N. Davidson (1999). Global review of wetland resources and priorities for wetland inventory - Summary Report, Wetlands International and the Environmental Research Institute of the Supervising Scientist, Australia.
- Gillilan, D. M. and T. C. Brown (1997). Instream flow protection: seeking a balance in Western water use. Washington, D.C., Island Press.
- Hafi, A., S. Beare, et al. (2005). Water Options for Environmental Flows, Australian Bureau of Agricultural and Resource Economics, Natural Resource Management Division, Australian Government Department of Agriculture, Fisheries and Forestry.
- Hansen, L. and A. Hallam (1991). "National estimates of the recreational value of stream flow." Water Resources Research 27(2): 167-175.

- Hirji, R. and T. Panella (2003). "Evolving policy reforms and experiences for addressing downstream impacts in World Bank water resources projects." River Research and Applications 19(5-6): 667-681.
- Howitt, R. and K. Hansen (2005). "The Evolving Western Water Markets." Choices 20(1): 59-63.
- (IFC), Instream Flow Council (2002). Instream flows for riverine resource stewardship. Lansing, MI, Instream Flow Council.
- Katz, D. (2006). Going with the Flow: Preserving and restoring instream water allocations. The World's Water: 2006-2007: The Biennial Report on Freshwater Resources. P. Gleick, H. Cooley, D. Katz and E. Lee. Washington D.C., Island Press: 29-49.
- King, J., R. Tharme, et al. (1999). Definition and Implementation of Instream flows. Cape Town, South Africa, World Commission on Dams - Thematic Review II.1: Dams, ecosystem functions and environmental restoration.
- Landry, C. J. (1998). "Market transfers of water for environmental protection in the western United States." Water Policy 1(5): 457-469.
- Loomis, J. (1987). "The economic value of instream flow: methodology, and benefit estimates of optimum flow." Journal of Environmental Management 24(1): 73-90.
- Loomis, J. B. (1998). "Estimating the public's values for instream flow: Economic techniques and dollar values." Journal Of The American Water Resources Association 34(5): 1007-1014.
- Loomis, J. B., K. Quattlebaum, et al. (2003). "Expanding Institutional Arrangements for Acquiring Water for Environmental Purposes: Transactions Evidence for the Western United States." International Journal of Water Resources Development 19: 21-28.
- McKinney, M. and J. Taylor (1988). Western state instream flow programs: A comparative assessment. Fort Collins, CO, National Ecology Research Center, Fish and Wildlife Service, U.S. Dept. of Interior.
- (NPS), National Park Service (1995). Economic Impacts of Protecting Rivers, Trails and Greenway Corridors. D. o. Interior, National Park Service (NPS).
- (NPS), National Park Service (2001). Economic benefits of conserved rivers: An annotated bibliography. D. o. t. Interior, National Park Service.
- Nieuwoudt, W. L. and R. M. Armitage (2004). "Water market transfers in South Africa: Two case studies." Water Resources Research 40.
- Petts, G. E. (1996). "Water allocation to protect river ecosystems." Regulated Rivers-Research & Management 12(4-5): 353-365.
- Poff, N. L., J. D. Allan, et al. (1997). "The natural flow regime." Bioscience 47(11): 769-784.
- Postel, S. and B. D. Richter (2003). Rivers for life: managing water for people and nature. Washington, DC, Island Press.
- Richter, B. D., J. V. Baumgartner, et al. (1996). "A method for assessing hydrologic alteration within ecosystems." Conservation Biology 10(4): 1163-1174.
- Richter, B. D., J. V. Baumgartner, et al. (1997). "How much water does a river need?" Freshwater Biology 37(1): 231-249.
- Scanlon, J. and A. Iza (2004). "International Legal Foundations for Environmental Flows." Yearbook of International Law: 81-100.
- Stalnaker, C., B. L. Lamb, et al. (1995). The Instream Flow Incremental Methodology: A primer for IFIM. Fort Collins, CO, National Biological Service: 45.
- Tennant, D. L. (1976). "Instream flow regimes for fish, wildlife, recreation and related environmental resources." Fisheries 1(4): 6-10.
- Tharme, R. (2003). "A global perspective on environmental flow assessment: Emerging trends in the development and application of environmental flow methodologies for rivers." River Research and Applications 19(5-6): 397-441.
- Tisdell, J. G. (2001). "The environmental impact of water markets: An Australian case-study." Journal of Environmental Management 62(1): 113-120.

Ward, F. A. and J. F. Booker (2003). "Economic Costs and Benefits of Instream Flow Protection for Endangered Species in an International Basin." Journal of The American Water Resources Association **39**(2): 427-440.

Wilkinson, M. (2008). Farmers won't go with flow. Sydney Morning Herald. Sydney.

Wilson, M. A. and S. R. Carpenter (1999). "Economic Valuation of Freshwater Ecosystem Services in the United States: 1971-1997." Ecological Applications **9**(3): 772-783.

Young, R. A. (1986). "Why Are There so Few Transactions among Water Users?" American Journal of Agricultural Economics **68**(5): 1143-1151.