CHAPTER

27 MOVING FORWARD: THE IMPLEMENTATION CHALLENGE FOR ENVIRONMENTAL WATER MANAGEMENT

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27.1 INTRODUCTION

Like most environmentally centered disciplines, the field of environmental water management is relatively young. The origins of modern environmental water praxis stem from efforts in the 1970s, mostly to mitigate the impacts of onstream dams by releasing minimum flows to maintain habitat for individual species (Acreman and Dunbar, 2004; Tennant, 1976; Tharme, 2003). Much of the early work was led by water engineers who recognized that hydraulic properties of the river, particularly depth and velocity, were important in defining physical habitat availability for sport fish such as salmon and trout (Bovee and Milhous, 1978; Milhous et al., 1989). This work evolved into the fields of ecohydraulics and ecohydrology. Ecohydraulics extended into microscale processes such as flow turbulence (Wilkes et al., 2013). In a somewhat parallel research stream, ecohydrology saw the growing collaboration between hydrologists and ecologists focused on broader relationships between river flow and ecosystem condition, moving beyond the hydraulic habitat requirements of individual organisms (Dunbar and Creman, 2001; Nestler et al., in review; Chapter 11). The importance of the environmental water regime in sustaining overall ecosystem structure and process became widely accepted in the 1990s (Richter et al., 1997), underscored by the seminal paper of Poff et al. (1997) on the natural flow paradigm, and followed by publication of flow−ecology principles (Bunn and Arthington, 2002; Nilsson and Svedmark, 2002).

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The concept of environmental water regimes as essential elements of sustainable water resource management in river basins was consolidated in the 2000s, with such regimes increasingly recognized for both their ecological and societal values (King et al., 2003; Poff and Matthews, 2013). In systems that remain relatively natural, environmental water regimes can be established to protect key river objectives. However, there has been increasing recognition that few rivers retain their natural flows or ecological integrity because of anthropogenic alteration of the environment. In many instances, therefore, conserving or restoring the range of flow variability experienced by a river under natural conditions is simply not realistic or societally desirable. Instead, there is a need to place more attention on the flow management of emerging and future hybrid and novel ecosystems (Acreman et al., 2014). Here, as in the case of heavily modified rivers, the objective may be to conserve targeted aspects of a river ecosystem for specific, predefined purposes such as recovering endangered species or maximizing benefits to people in line with the *Sustainable Development Goals (SDGs)*, for instance, rather than attempting to restore the river's condition prior to major development.

In 2007, the Brisbane Declaration established an international consensus on the definition and principles of environmental flows (or water levels) and defined environmental flow management as providing:

> ... *the water flows needed to sustain freshwater and estuarine ecosystems in coexistence with agriculture, industry, and cities. The goal of environmental flow management is to restore and maintain the socially valued benefits of healthy, resilient freshwater ecosystems through participatory decision making informed by sound science.*

To achieve this, the Brisbane Declaration (2007) called for commitment to a number of key actions for maintaining and restoring environmental water regimes, many of which were aimed at expanding the number of river systems where environmental water regimes are being implemented, broadening stakeholder engagement and participatory decision making, and building the networks and capacity required to initiate, maintain, and enforce environmental water implementation.

In the decade since the Brisbane Declaration was drafted, how far have we come in meeting this commitment? This is a difficult question to answer, as there is no clear, globally consistent approach to measuring how successfully environmental water practice has responded, and no widely accepted global database for sharing information on where and how environmental water is provided. The lack of international benchmarks and databases is evidence of a still-fragmented landscape for environmental water management, as well as of insufficient prioritization of investment in the assessment of its global impact. However, the wide range of experts, approaches, and case studies across different subdisciplines of environmental water brought together in this book have demonstrated that there has been significant progress on several fronts.

First, there has been a clear broadening in the concept of *environmental water management* to reflect the rationale of the Brisbane Declaration. Methodologies for environmental flows assessment now incorporate stakeholder values, participation, and codesign, and recognize the dual role of environmental water in supporting ecological and societal values and benefits, especially for those people who directly rely on river ecosystems for their livelihoods (King et al., 2003; Poff and Matthews, 2013; Ziv et al., 2012). Second, there has been significant progress in the development of the science that underpins the assessment of environmental water requirements (Arthington, 2015; Stewardson and Webb, 2010). Third, we have seen environmental water discussed in high-level forums and incorporated into national and international water policy and legislation across the globe (Hirji and Davis, 2009; Le Quesne et al., 2010; O'Donnell, 2013). This is, for example, reflected in the rapid growth in the number of government agencies and nongovernment entities funding environmental water projects (Garrick and O'Donnell, 2016; Garrick et al., 2011; Pahl-Wostl et al., 2013; Richter and Thomas, 2007; see Chapters 17−19).

Despite this progress, there remain significant challenges in the delivery of environmental water regimes on the ground. This persistent, overarching implementation challenge is revealed in each section of this book. This final chapter focuses on directions to achieve successful implementation of environmental water policies into the future, and is organized around six key questions:

1. How much water do rivers need?
2. How do we increase the number of rivers where environmental water is provided?
3. How can we embed environmental water management as a core element of water resource planning?
4. How can knowledge and experience be transferred and scaled more easily?
5. How can we enhance the legitimacy of environmental water programs?
6. How can we support the inclusion of adaptive management as standard practice?

Addressing any one of these questions requires the experience and knowledge held in shared skills across multiple disciplines. This is a recurring theme throughout this book: environmental water management is more successful when it actively seeks to incorporate a diverse range of expertise and interests.

27.2 HOW MUCH WATER DO RIVERS NEED?

Twenty years ago, Richter et al. (1997) asked the question "How much water does a river need?" In Chapter 9, Jackson recast this question as "How much water does a culture need?" to highlight the social and cultural complexity of societal relationships with water, and the need for greater integration of social dimensions in environmental water management. The challenge of defining an environmental water regime is thus twofold; understanding and incorporating the shared objectives and values of the river, along with understanding and incorporating the scientific links between flow and ecosystem condition (Finn and Jackson, 2011). Although there have been considerable advances in both these aspects of environmental water management, there remain areas for advancement.

A central element of water management is the establishment of a shared vision for the river system that acknowledges the diverse uses of the resource and ways in which cultures value and benefit from the natural environment. The amount of water a river needs is inherently linked to the sort of river the society wants, while also recognizing the intrinsic rights of nature. There are many challenges when defining a vision for a river and objectives for environmental water. First, our values change over time both due to our priorities and changes in the way we interact with nature. For example, it is well documented that willingness-to-pay for environmental outcomes increases with wealth and economic security (Whittington, 2010). There are more options available in a river system that is not heavily developed or relied upon for human uses. In heavily developed systems, while we increasingly recognize the value of a healthy environment to support our lives, we know that restoring systems to a natural state is unrealistic if they are to simultaneously meet modern human water needs. Increasing population growth and climate change are also driving systems to evolve in novel ways, making the relevance of the term *natural* for understanding river system objectives uncertain (Chapter 11). It is also possible that there will be substantial shifts in the way communities interact with nature in the not-so-distant future. For example, robotics is increasingly being used to support agriculture, changing the way that farms and rural communities may be structured. Artificial environments are being created to meet the needs of residents in urban centers, either through created parklands, or in the future, through documentaries and augmented or virtual reality. Simultaneously, transport options may make many remote river basins more readily accessible for recreation. We do not claim to know how these aspects will shape the way river basins are used and valued, but rather highlight that planning and policy must recognize that there will be shifting values and objectives, possibly including those pertinent to environmental water management, as technologies, economies, and societies change.

Second, much of the early work in environmental water science and the development of environmental flows assessment methods took place in developed countries in temperate climatic regions; other methods have been developed in semi-arid and tropical regions and/or applied in less developed countries (Tharme, 2003). It is important to consider that people in different countries often think about and experience the environment and river systems differently, because of differing cultural values, beliefs, and practices, along with differing needs for river natural resources (Daniell, 2015; Enserink et al., 2007). Varying climatic regimes also lead to a diversity of river socio-ecological systems and flow regimes, and different relationships between them. Knowledge of the environment in different settings is shaped through personal experience, and then often transferred through generations. Values and objectives developed and transmitted through customary approaches may be difficult for scientists and managers to capture or fully comprehend using the current common tools for environmental flows assessments (Christie et al., 2012). Finally, and perhaps in a similar vein, there has been limited involvement of indigenous communities in defining water needs and values within the framework of environmental water assessments. This is despite river systems being central to many indigenous cultures, livelihoods, and values (Finn and Jackson, 2011). The utilitarian values that underpin many of our existing water resource management systems are oftentimes at odds with the relational values of many indigenous communities with river systems, where they support relationships between each other and nonhuman nature (Chapter 9). Reconciling these distinct approaches to valuing a river system and creating a shared vision and objectives for a river is an essential element of progressive environmental water management.

Many of the world's river systems are managed through water resources infrastructure such as dams, with thousands of new dams in planning and construction (Winemiller et al., 2016; Zarfl et al., 2015). In these systems, over time the environment both downstream and upstream of these dams becomes increasingly modified from its original state. Where water infrastructure is still in the planning stage, greater opportunity exists to avoid and/or minimize the potential socio-ecological effects of flow alteration at a system scale, particularly through appropriate dam placement (Opperman et al., 2015) and the introduction of dam design features and operational rules that enable environment water delivery (Richter and Thomas, 2007; Chapter 21). Once the construction stage is reached, opportunities to reverse ecological degradation and shift systems in the direction of their predam state are often severely constrained by the design features or operational requirements of the dam to meet its economic purpose. In this situation, the relevance of the natural flow regime as a reference or target may not be appropriate for dams that severely modify downstream biophysical processes. It may be more appropriate to *design* an environmental water regime that meets the multiple objectives (consumptive and environmental) of the system (Acreman et al., 2014). "The idea of being able to define and quantify the components of the flow hydrograph and assemble them into an environmental flow regime that meets a particular set of ecological and social objectives can be thought of as a 'designer' approach, producing environmental flows that support desired ecosystem states or provide desired ecosystem services" (Acreman et al., 2014). Although this concept is appealing and implicitly underpins the development of many environmental water regimes in practice (e.g., GBCMA, 2014), there remains a significant challenge as to how to design and manage a flow regime to ensure that the complex needs of the environment are supported in the longer term (Acreman et al., 2014; Arthington, 2015; Arthington et al., 2006; Harman and Stewardson, 2005). This will usually require trade-offs between different river-level objectives (e.g., agriculture, hydropower, urban, and environmental), and indeed between different elements of the river ecosystem (e.g., fish and vegetation). A manager must decide how to operate the water resource system and its storages to achieve a socially desirable outcome that meets both environmental and societal needs (Acreman et al., 2014; Poff et al., 2016). This highlights the need for decision frameworks that facilitate these trade-off decisions and account for the various societal objectives that intersect with water resource management.

Although our understanding of flow–ecology relationships has significantly improved over the past 20 years (Arthington, 2015), there are still gaps in our knowledge of the ecological effects of flow alterations (Poff and Zimmerman, 2010; Webb et al., 2013). A major challenge is to undertake controlled water management experiments at the catchment scale, with much research still reliant on the occurrence of changing flow conditions during floods or droughts for advancing the knowledge base (Konrad et al., 2011; Olden et al., 2014). More collaboration between dam owners/operators, landholders, and scientists is needed to codevelop hypotheses and provide robust tests of these via flow manipulation experiments (Poff et al., 2003). In addition, new environmental and management challenges in the future will require different scientific information to support management decisions. The research agenda has to anticipate these challenges in order to support managers as the implications of new challenges are realized. Here, we focus on just two of these future challenges: (1) active environmental water management and (2) climate change.

Chapter 19 describes the emergence of active environmental water management. Recall that *active* environmental water management refers to those allocation mechanisms that require ongoing decision making concerning when and how to use environmental water to achieve the desired outcomes. As more river systems are altered by water resource development and/or reach their limits of sustainability, it is likely that there will be an increase in jurisdictions adopting allocation mechanisms for environmental water that require active management. Chapter 11 discusses some of the specific planning and operational challenges of actively managing environmental water. Importantly, active management highlights two distinct, but nested cycles of adaptive management (Chapter 25). The first is the planning cycle, for instance setting the longer-term objectives and priorities for the system (Chapter 23). The second is the implementation cycle, for instance the ongoing decisions around how to operationalize and use the environmental water from day to day, seasonally, and from year to year (Chapter 24).

Both the planning and implementation cycles of environmental water management can be improved through the use of conceptual models that (1) link the decisions available (e.g., to release environmental water at different spatial and temporal scales) to the objectives being managed for and (2) provide quantitative information to show the benefits of one flow decision over another. However, the resolution or granularity of information required differs between the planning and implementation cycles, with finer-scale information needed for implementation (Horne et al., in press). The implementation cycle, in contrast to long-term planning, has the advantage of being able to adjust the environmental water regime in a dynamic way to account for feedbacks and state transition information for environmental endpoints (Overton et al., 2014; Shenton et al., 2012). It also allows the flexibility to adjust the details of flow events (e.g., the peak magnitude of a flow event and its duration) to meet real-time assessments of adequacy. However, managers require information to inform the precise timing of when flow is required, and consideration of releases for other users and unregulated inflows in a particular season. Transparent and detailed information on the marginal return of a decision (e.g., whether delivery of half the water would provide half the benefit) thus becomes important for implementation, with these calculations needing to take place at a within-year timescale. As the value of water increases, so too does the importance of these decisions. As it will usually not be possible to provide the complete desired environmental water regime in all years, making the best use of the water available will require an understanding of the benefits or risks of providing one component of the flow regime without (or instead of) another, or providing one flow component, but at less than the recommended magnitude (Gippel et al., 2009; Richter et al., 2006). Multiyear sequencing of environmental water releases also becomes relevant; in how many years out of five does a particular flow event need to be provided? Future environmental flows assessment methods will need to respond to these information needs to allow adaptive management at the implementation scale. Moreover, there will be a substantial role for improved decision support tools to assist environmental managers to assimilate and assess the implications of this fine-grained information in order to implement active management (Horne et al., 2016). In situations where the available environmental water is constrained, the question changes from how much water is needed to how do we best manage the water available for the environment.

Climate change is also creating new challenges for environmental water science (see Chapter 11 and 14) and management. Over the history of environmental water management, the assumption of a stationary climate has prevailed, and this has allowed statistical analysis of historical flow regimes to be used in planning future flow allocations. Contemporary environmental flows assessment approaches such as *Ecological Limits of Hydrologic Alteration* (*ELOHA*; Poff et al., 2010) and sustainability boundaries (Richter et al., 2012) still rely on this simplifying assumption. It is now recognized that the climate is changing and future hydrologic regimes are likely to deviate substantially from historical *reference* conditions in many regions (e.g., Reidy Liermann et al., 2012). Thus, from a water management point of view, uncertainty about future flows complicates the planning and implementation cycles necessary to achieve and sustain effective environmental water regimes. Uncertainty over available future water will likely intensify debates around environmental water allocations, and around water allocation more broadly.

Beyond the water management challenge, however, other challenges are emerging for the practice of environmental water management as the climate changes. Warming temperatures are modifying species performance and fitness, and changing interactions among species in ways that are already causing shifts in species distributions and ecosystem processes. Thus, the notion of reference ecological conditions is also shifting and creating a need to move away from a simple statistical association between average hydrologic regime components and time-averaged ecological states toward a more *process-based* understanding of the linkages between hydrologic regime dynamics (extreme events, antecedent flows) and ecological processes (see Chapter 11).

The shifting landscape of hydrologic and ecological baselines (Kopf et al., 2015) creates new impetus for environmental water scientists and managers to engage stakeholders in defining socially desirable ecological targets that can be achieved under future water regimes. To date there are few examples where these issues have begun to be considered, and large uncertainties are liable to remain a feature of forecasting efforts for some time. New decision support tools will be required, to aid in the identification of realizable objectives and assess the likelihood of achieving them through well-defined management interventions (Poff et al., 2016).

Finding the *answer* to the question of how much water a river needs and for what purposes is thus a complex undertaking with each river being different, and also having different needs over time. Both environmental and societal drivers will define the appropriate environmental water regime, but the challenge remains to develop and use the tools necessary to answer this question for any single application. Rather than providing a *definitive answer*, refining the approach to objective setting, and strengthening our scientific knowledge on what different benefits flow regimes will be likely to deliver, will improve the robustness of our approach to providing environmental water under changing futures (Davies et al., 2014).

27.3 HOW DO WE INCREASE THE NUMBER OF RIVERS WHERE ENVIRONMENTAL WATER IS PROVIDED?

The Brisbane Declaration argued for considerable and rapid expansion of the number of locations around the world where environmental water regimes are in place. How do we best support the implementation of environmental water into new locations? Moore (2004) surveyed 272 individuals involved in environmental water management, across a range of organizations, and asked respondents how the concept of environmental water was initially established in their various river basins and countries. The results show that public awareness and recognition of the importance of river flows to local livelihoods were both important factors. Interestingly, the introduction of environmental flows assessment projects and expertise was also seen as a major driver. Environmental flows assessments, particularly when there is stakeholder engagement, can lead to significant, positive changes in community attitudes concerning water resource management (King et al., 1999; Moore, 2004).

Moore (2004) also asked respondents to identify the major difficulties and obstacles to implementing environmental water regimes in their region (Fig. 27.1). The respondents indicated that increased public awareness would help build political will and effective stakeholder engagement (both identified as obstacles in Fig. 27.1). Similarly, recognition of the importance of local livelihoods (a success factor identified in Moore, 2004) is linked to having an understanding of the socio-economic costs and benefits associated with environmental water (an identified obstacle; Fig. 27.1). Institutional arrangements, including inadequate or inappropriate funding of environmental water projects, along with insufficient technical capacity, are also identified as common obstacles to the implementation of environmental water regimes.

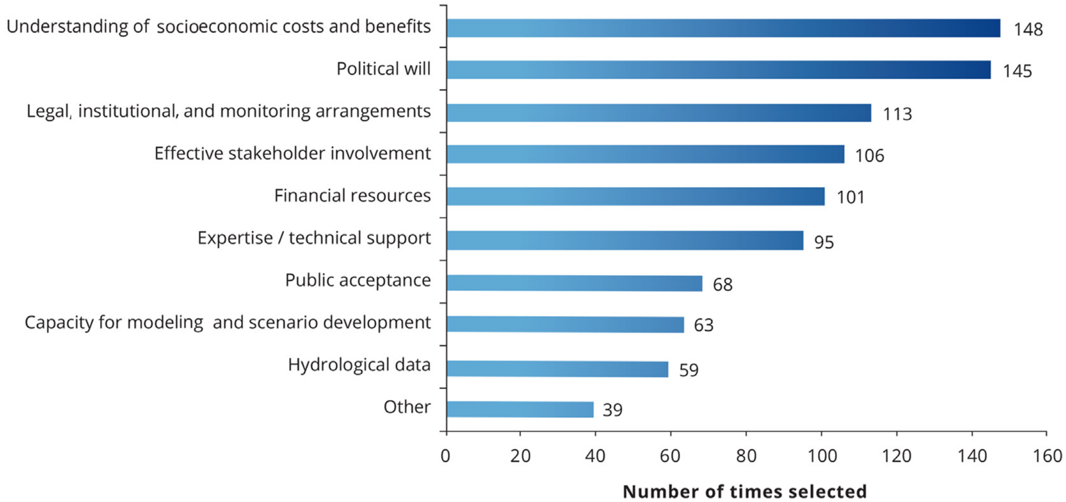

FIGURE 27.1

Survey results showing the major difficulties and obstacles to implementation of environmental water programs within the respondents' areas.

Source: Moore (2004)

Governments need sufficient evidence to make the case for reform (OECD, 2012). Much of the world's species richness is located in developing countries, and is thus under pressure from efforts to stimulate economic growth and alleviate poverty (Fazey et al., 2005; Winemiller et al., 2016). In systems where there is high demand for water, allocation of water to the environment will likely require a trade-off with consumptive water uses (see Chapter 16). Ecosystem services—the contributions of biodiversity, ecosystem structure, and function to human well-being (see Chapter 8)—provides one potential mechanism to assess the benefits of environmental water regimes using a value and measurement system that aligns more closely with traditional economic outcomes from water resource use. Many developing countries are grappling with the challenges of poverty alleviation, human well-being, and economic development. There may thus be a heavier reliance on water resources to meet immediate human needs, making it difficult to consider longer-term ecosystem needs and ecosystem services for future generations (Christie et al., 2012). This has led some experts to conclude that the goals of poverty reduction and environmental management are incompatible (Dalal-Clayton and Bass, 2009). In these cases, identifying ecosystem services provided by environmental water may improve community understanding and support, as well as provide the evidence to support reform. People often unknowingly rely on ecosystem services. There remain significant challenges for identifying and communicating these ecosystem services. Moreover, there are further challenges for economic valuation techniques (as discussed in Chapter 8), and these are exacerbated in developing countries where limited valuation of environmental goods and services has occurred (Christie et al., 2012; Kenter et al., 2011) and other or complementary means of valuing river resources and ecosystem integrity are recognized. These limitations can, in part, be addressed through local engagement and capacity building in the identification and valuation of ecosystem services (Christie et al., 2012), and through the use of nonvaluation techniques (see Chapter 8).

Although ecosystem services are likely to be an important tool for expanding the implementation of environmental water, it is important to recognize the long-running and unresolved debate about how to value nature. There are those who suggest nature is important for the benefits it provides humans, and others who see a moral responsibility to protect nature for its own sake, for instance its intrinsic value (Davidson, 2013). There is debate around how well ecosystem services concepts capture intrinsic biodiversity and environment values (Davidson, 2013; Dudgeon, 2014). As an extreme position, Krieger (1973) suggested that if the *value* of trees is purely around services to humans, it may be that a plastic replica of a tree could provide some of these same services. We suspect that most people would have some underlying discomfort with this position, as they perceive some value from knowing that nature exists and knowing it will be there for future generations. This remains a core challenge for river basin communities; how much importance should they place on the *existence* or *intrinsic* value of nature compared to the immediate human needs from the river? In New Zealand, the Whanganui River has now been recognized as a person when it comes to the law, giving it rights and interests for its own sake. This recognizes the river as a living force that should be respected and protected in its own right, not just for the benefit of development and human well-being (Calderwood, 2016).

Financing of water reform and implementation remains an ongoing struggle in many countries (OECD, 2012), and a recognized barrier to the implementation of environmental water management (Moore, 2004). Where major infrastructure projects are funded by donor agencies, the implementation of an environmental water program could be linked to the funding criteria and included within the project costings (Hirji and Davis, 2009). An alternative approach is to purchase water for the environment from existing uses, managed through government or private actors such as *nongovernment organizations* (*NGOs*; Chapter 18). This is readily achieved in systems that are well-licensed with existing water markets (e.g., the Murray—Darling Basin; Hart, 2015), but can also be achieved through strong stakeholder engagement in systems where there is no existing water market (e.g., NGOs operating in parts of the western United States; Garrick et al., 2009; Horne et al., 2008). Such purchasing may currently be occurring in only a handful of locations (most notably the western United States and Australia), but is expected to become more important in the future. Where funds or other resources are limited, there may be a role for the rapid rollout of precautionary environmental flows assessments that are inexpensive to implement and can be done with limited empirical information (Richter et al., 2012; Tharme, 2003). These would then be followed later by more robust environmental flows assessments (a triage type approach). However, it is important to recognize that where there are significant economic trade-offs with providing environmental water, it is likely that the precautionary approach will fall short of providing adequate information to justify limiting economic growth. Even with a precautionary environmental water regime determined, there would be an ongoing financial cost associated with implementation and enforcement.

A key opportunity for achieving implementation of environmental water regimes is to build on global commitments that require environmental water. The SDGs (officially known as Transforming Our World: the 2030 Agenda for Sustainable Development) provide a set of 169 targets developed by an intergovernmental process under United Nations Resolution A/RES/70/1 of September 25, 2015 (http://www.un.org/sustainabledevelopment/). Healthy terrestrial and aquatic ecosystems are explicit in Goal 15 and implicit within Goal 3 (Good Health and Well-being) and Goal 6 (Clean Water and Sanitation). Goal 15 specifies targets such as by 2020 “ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services,” “reduce the degradation of natural habitats, halt the loss of biodiversity,” “introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems,” and “integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts.” A key challenge is to embed the importance of environmental water into the language of the SDGs through the use of environmental water indicators for measuring performance of the SDGs to demonstrate how healthy river ecosystems can deliver human health and well-being. One example of success with this type of approach is the recognition of the importance of environmental water for achieving the goals of the European Water Framework Directive, namely that all rivers in Europe achieve *good* ecological status by 2020. The European Commission is engaging with the environmental water science community to determine just how to achieve this; a guidance document has recently been published by a pan-European ecological flows group (European Commission, 2015). A further challenge lies in providing accessible and transferrable tools and techniques to achieve these goals (discussed further in Section 27.5).

Until recently, environmental water expertise and experience was held by a few groups distributed around the world, principally in North America, Europe, South Africa, Australia, and New Zealand. Capacity building has been increasingly incorporated in the implementation of environmental water projects (e.g., Acreman et al., 2006). In parallel, environmental water issues have been incorporated into academic teaching and research programs. In addition, programs such as the International Union for Conservation of Nature’s Water and Nature Initiative have provided workshops and involvement in environmental water projects in 12 river basins covering 30 countries worldwide (http://www.waterandnature.org). These forums play a role in building awareness of the issue of environmental water and its importance at a global scale. Similarly, aid organizations, universities, and NGOs have built capacity in China and India (Gippel and Speed, 2010; Gopal, 2013). Specific training has been complemented by broader activities such as the establishment of environmental water networks. However, short-term funding has limited ongoing viability of such networks.

27.4 HOW CAN WE EMBED ENVIRONMENTAL WATER MANAGEMENT AS A CORE ELEMENT OF WATER RESOURCE PLANNING?

Successful implementation of environmental water management requires institutional structures that facilitate the allocation of environmental water, but importantly, integrate this with the broader area of water resource management and catchment/land-use planning. In its most basic form, this requires institutions to account for and monitor what water is available and where that water is going (Chapter 16). In many countries, water policy is developing faster than the data infrastructure to support policies, with the result that policy implementation often occurs in a data vacuum (Chapter 16). Designing and funding these information systems will be an essential element for increasing the implementation of environmental water.

To implement effective and sustainable reforms to provide environmental water, environmental mainstreaming is required; "the informed inclusion of relevant environmental concerns into the decisions of institutions that drive national and sectoral development policy, rules, plans, investment and action" (Dalal-Clayton and Bass, 2009). As a result of the initial advocacy role environmental organizations played in establishing the importance of instream river health, environmental water management is often siloed within water resource organizations. This limits the ability for novel integrated solutions and effective policy debate (Dalal-Clayton and Bass, 2009). Ideally, the governance structure for managing water resources would support concepts of conjunctive water uses (maximizing environmental outcomes from the delivery of water to consumptive uses as discussed in Chapter 21), rather than the usual competitive paradigm that is reinforced through institutional boundaries delineating environmental versus productive uses (Richter, 2010, 2014). Integrating environmental water within broader water resource management would also allow more nimble and informed responses to change (Dalal-Clayton and Bass, 2009).

As climate change impacts continue to create great uncertainty about (and change in) water availability, active discussions will be required around how these changes to supply are distributed among water users, and what changes are required to deliver water for both societal and environmental purposes (Poff et al., 2016). The institutional arrangements and environmental water allocation mechanisms should reflect conscious societally informed decisions around how water resources will be managed adaptively over time (see Chapters 17 and 19).

There are also challenges and opportunities for developing synergies between urban and rural water management, and development regimes that address keeping water in the landscape to reflect natural patterns of hydrological water balance (Grafton et al., 2015). Specifically, impervious urban areas typically have issues with excess flow production and insufficient capacity to retain and infiltrate water in the environment during storm events, whereas many rural areas have attenuated flows due to greater (constructed) water storage capacity and irrigation demand.

Importantly, water resource policy extends well beyond the government sectors that manage water resources, with many other sectors relying on water or influencing water resource outcomes. For example, energy, food, and water policies are all inherently linked. All efforts need to be made to ensure that they are coordinated with a shared vision so that policies from one sector do not adversely impact on other sectors and rather attempt to find mutual benefits (Hussey and Pittock, 2012; Pittock et al., 2013). The processes established to do this must be nimble enough not to hinder water resource policy with layers of bureaucracy.

27.5 HOW CAN KNOWLEDGE AND EXPERIENCE BE TRANSFERRED AND SCALED?

The challenge and urgency of protecting environmental water regimes is global, but significant advances in environmental water science and practice have been unevenly distributed among countries and global biophysical, social, cultural, and political settings (McClain and Anderson, 2015). A present-day cartogram of scientific knowledge regarding ecological responses to flow alteration and efforts to implement best environmental flows assessment practices would be heavily skewed toward North America, Europe, and Australia (Konrad et al., 2011; Poff and Zimmerman, 2010). In Africa, the Republic of South Africa passed ground-breaking legislation explicitly protecting river flows for basic human needs and ecosystems (RSA, 1998), and similar legislation has spread to neighboring countries in southern and eastern Africa (GoZ, 2002, 2011). South Africa has also contributed significantly to the development of holistic methodologies for environmental flows assessment (King et al., 2003, 2008), although implementation has been limited in that country. In Asia, China is emerging as a national leader in both environmental flows assessment research and cooperation between researchers and resource managers to improve practice in water resources management (Hou et al., 2007; Opperman and Guo, 2014; Sun et al., 2008). Research in the Mekong has significantly advanced knowledge of the coupled effects of basin-scale flow alteration on ecosystem function and human livelihoods (Molle et al., 2012; Ziv et al., 2012). In Latin America, Mexico has recently launched a scientifically rigorous and politically innovative effort to protect environmental water regimes nationwide, but research and practice across the rest of Latin America has been limited and irregular. Little or no information is available for other parts of the world.

Certainly, some prerequisites for achieving universal environmental water implementation are more ubiquitous. For example, United Nations processes emphasizing sustainable development over nearly 30 years (Drexhage and Murphy, 2010) have resulted in supportive international conventions and nearly universal reform of national laws and policies to require ecosystem protection. Dating from even earlier efforts, policy and practice in most countries acknowledge that a minimum level of flow should be maintained in rivers regardless of mounting pressures from other water uses. This perspective derives mainly from 19th- and 20th-century efforts to protect fishery resources and water quality in the interest of livelihoods and public health (Chandler, 1873; State of California, 1914). Although the specified minimum flows (e.g., Q95, Q10, or 10% of mean annual runoff) are generally insufficient to achieve modern social–ecological objectives, they do ensure that some amount of flow remains in perennial rivers everywhere. This international policy reform and acknowledgment of minimum flow requirements forms the foundation on which greater environmental water regime protection can be built.

Knowledge and experience gradually spread globally via numerous formal and informal mechanisms embedded in academic, professional, and governmental processes. However, the rapid pace of water resource development worldwide, and corresponding decline in freshwater ecosystems, require new strategic action on the part of the environmental water community to accelerate the pace of knowledge transfer, applied research, and implementation on the ground. Two interrelated elements are proposed as the pillars of an international strategy, with peripheral actions to extend the impact more broadly. The first element is to mainstream environmental water science and practice into major international science and development initiatives, thereby raising the profile of the topic and engaging the highest echelon of scientists and highest levels of practitioners and decision makers. Second, is to establish a global network of living laboratories (and related community of practice) at locations where advanced science, tools, and practice are being codesigned and codeveloped. These living laboratories could also include demonstration sites of best practice scaled to local conditions.

As mentioned earlier, the global community has agreed to the United Nations Sustainable Development Agenda 2030, which includes specific targets for freshwater ecosystem protection under Goal 6 and coastal resources under Goal 14 (http://www.un.org/sustainabledevelopment/). Environmental water requirements appear explicitly in indicators 6.4.2 (Level of water stress: Freshwater withdrawal as a percentage of available freshwater resources) and 6.6.1 (Change in the extent of water-related ecosystems over time; UN Water, 2016). These goals and targets align with the long-standing efforts of the Convention on Biological Diversity, Ramsar Convention, DIVERSITAS, and the more recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Together these initiatives represent a strong international commitment to protect and sustainably develop freshwater and coastal resources; they are also an invitation to the science community to engage in research supporting the achievement of stated environmental goals. In response, the international science community has launched multiple coordinated research initiatives. Examples include the eighth phase (2014–21) of UNESCO's International Hydrological Programme; the decade *Change in Hydrology and Society* of the International Association of Hydrological Sciences (2013–22); and Future Earth, the new program of the International Council for Science. Elements of water research appear in each of these initiatives, and their continued growth in conjunction with policy initiatives holds promise for extending environmental water science and practice more widely. Other efforts and initiatives appear at national and regional scales (Arthington et al., 2010).

Efforts to transfer and expand knowledge and experience in environmental flows assessment and water management should be further enhanced by establishing a network of living laboratories and demonstration sites focused on the science and practice of environmental water management. The term *living labs* refers to structured collaborations between researchers and the users of research outputs to codesign and codevelop research activities (Van der Walt et al., 2009). This approach helps to embed environmental water research in ongoing water resource management and policy making so that research products are better tailored to the needs of end users and can be implemented more effectively and efficiently. An early example of this approach is the Sustainable Rivers Project, which partnered scientists from The Nature Conservancy with water managers of the US Army Corps of Engineers to investigate and demonstrate how dams could be reoperated to meet improved ecological objectives among multiple options (Warner et al., 2014; see also Chapter 25). Today there are examples of such partnerships around the world. Linking these efforts in a coordinated network would provide the research infrastructure to apply commonly adopted approaches to hypothesis setting and align monitoring programs regionally and globally, converting quality data into usable tools.

Increased attention must also be given to better understand the social dimensions of environmental water management. Wescoat (2009) argued that the 21st century would be a period of increasing circulation of expertise about water challenges and governance responses. Environmental water management is a prime example, where researchers and practitioners have exchanged lessons about the policy and governance approaches to establish and manage environmental water across diverse geographical and governance settings, and with different degrees of water scarcity over time. Successful environmental water management requires effective frameworks and methods for policy transfer, or preferably translation (Mukhtarov and Daniell, 2017), that allow for adaptations of the policies to fit the different contexts, nature of the problems, and the range of relevant policy settings and instruments (Swainson and de Loe, 2011). For this reason, Australia and the United States have been extensively compared, illustrating the contrasting roles of public and private organizations in the acquisition of delivery of environmental water in river systems, coupled with the common need for resources, accountability, and legitimacy (Garrick et al., 2009; Horne et al., 2008). A network of living labs offers a further opportunity to forge communities of practice needed to translate lessons and learn from similarities and differences in both rural and urban settings. The frameworks, approaches, and case studies collected by this book demonstrate this potential.

The peer-reviewed scientific literature is an essential dissemination channel for credible research results, but it is insufficient to reach the full spectrum of international scientists, practitioners, and decision makers. Living labs or other mechanisms to share successes, challenges, and tools for implementation allow outcomes to be tailored to those implementing environmental water regimes. Importantly, they also allow discussion of the institutional arrangements needed to support environmental water implementation.

27.6 HOW CAN WE ENHANCE THE LEGITIMACY OF ENVIRONMENTAL WATER PROGRAMS?

The primary normative guideline for governance... is legitimacy.

Wolf (2002, p. 40)

Measuring success for environmental water programs has typically focused on two metrics: effectiveness and efficiency. Did the environmental water provided perform the ecological function that was required, for instance effectiveness (McCoy, 2015)? And did it do so efficiently, for instance at a cost that was acceptable, and minimized where practicable (e.g., Aylward et al., 2016)? In debates about the need for environmental water, these metrics are essential to the decision to provide water to the environment, especially when doing so means that it is not provided to other consumptive uses. Indeed, one of the signs of increasing maturity in environmental water management is that it now actively considers whether the environmental water is being provided in a way that maximizes environmental benefit and minimizes costs (Garrick, 2015; Horne et al., 2016; Pittock and Lankford, 2010). However, to date there has been limited reporting on the broader social benefits of healthy rivers in the landscape as a result of environmental watering activities.

We are starting to understand that legitimacy is crucial to the long-term success of environmental water programs. In 2015, the *Organization for Economic Cooperation and Development (OECD)* identified trust and engagement, alongside efficiency and effectiveness, as the core elements of good water governance (OECD, 2015). Chapter 26 defines legitimacy as both *input* and *output* legitimacy

(Scharpf, 1999). Output legitimacy includes measures of efficacy, and is often relied on to assert the legitimacy of environmental water programs: they are considered to be legitimate because they worked. However, output legitimacy also includes awareness, acceptance, and a common approach to shared problem solving (Hogl et al., 2012), all of which depend on the *process* used to implement the environmental water program. The process is a function of input legitimacy, and requires explicit consideration of access, equal representation, transparency, accountability, consultation and cooperation, independence, and credibility (Hogl et al., 2012).

Chapter 26 places legitimacy alongside effectiveness and efficiency as one of the core measures of success for environmental water programs. There are two important practical lessons that emerge from this inclusion of legitimacy. First, it is essential to invest in building legitimacy at every stage in an environmental water program from environmental water agenda setting and the environmental flows assessment, through to the mechanisms to provide them, to the ongoing implementation and management of environmental water. In particular, this requires acknowledgment that the first step for all environmental water programs is the development of a shared awareness and acceptance by stakeholders that the environment itself needs water in particular quantities, timing, and qualities to meet specific objectives, including those of ecosystem maintenance and functionality. Failing to take the time to ensure that such legitimacy for the program has been established at this point of agenda setting may undermine all future phases of policy making and implementation of the proposed program. Indeed, it may leave it vulnerable to defeat in a political battle where a coalition of stakeholders opposing the environmental water has its agenda represented in the policy decisions (Daniell et al., 2014). It may also lead to feelings of injustice if some stakeholders consider that they have been treated unfairly by the development of the environmental water program, having not been adequately involved in its development (Lukasiewicz and Dare, 2016). We now understand that legitimacy is much more than a function of the outcomes of an environmental water program or the quality of the scientific evidence underpinning it, and is unlikely to be built without significant investment in stakeholder engagement and communication (see Chapter 7).

However, building and maintaining legitimacy may well increase the upfront cost of an environmental water program. Garrick and O'Donnell (2016) showed that investing in legitimacy may increase the transaction costs of water recovery for the environment, and may extend the duration of water recovery programs, so that it takes more time and more money to reach the intended goal. However, failing to invest in legitimacy, specifically in the implementation of a range of stakeholder engagement methods to build and maintain it (Daniell, 2011), may undermine an otherwise successful environmental water recovery program at a later time, deferring costs until the future. For example, the environmental water recovery program in the Murray–Darling Basin in Australia used water trading to rapidly acquire large volumes of water for the environment. However, this water recovery came to be viewed as deeply problematic by irrigators, who successfully lobbied the government to impose a new, lower limit on the volume of water that could be recovered for the environment by purchasing it from other users (The Hon. Greg Hunt MP and The Hon. Bob Baldwin MP, 14 September 2015). Remaining environmental water to be recovered under the Basin Plan must be secured through infrastructure-based efficiency measures, which are more expensive than direct purchases, and may not deliver the desired ecological benefits (Bond et al., 2014). Thus, the failure to secure the support of other water users will now be a substantial cost to the Basin Plan water recovery program. In the Columbia River Basin in North America, initial implementation of environmental water regimes involved acquisition of water rights for instream uses under the principle of *buy-and-dry*, triggering political and legal resistance from communities affected by the reduction of irrigation and associated industries, and threatening to reverse the regulatory reforms enabling environmental water transactions (Pilz, 2006). In the decade since, there has been considerable work to rebuild the legitimacy and trust that had been eroded, including an explicit rejection of the buy-and-dry philosophy by the National Fish and Wildlife Foundation and the Columbia Water Transactions Program.

Developing effective stakeholder engagement processes can thus be one important means of enhancing the legitimacy of an environmental water program. However, building a real partnership between stakeholders, so that they are all committed to achieving a successful environmental water outcome, takes time, effort, trust, and humility (see Chapter 7). It requires experts to admit that they may not have all the answers, and policy makers and practitioners to listen to the diversity of views that can inform environmental water management. One often missing element is a specific investment in building partnerships with indigenous peoples, particularly in the context of historical colonization and disenfranchisement (Robinson et al., 2015). The legitimacy of an environmental water program will likely depend on giving all voices equal opportunity to be heard and to influence the design and implementation of the program, accepting that there are many different forms of knowledge. The acceptance by practitioners and scientists that environmental water management is primarily a social process within a wider complex social–ecological system as opposed to a scientific management process has been slow to resonate within the field (Arthington, 2015). Participatory decision making thus remains poorly integrated into many existing environmental water policies and programs. However, there are increasing numbers of instances where stakeholder engagement has been adequately funded and integrated into such programs. These include instances where stakeholder engagement is a compulsory part of legal frameworks such as in the European Union Water Framework Directive (EU, 2000, 2002; see also von Korff et al., 2012), and where conflict and transaction costs have been reduced and legitimacy enhanced through stakeholder engagement investments in environmental water (see Chapter 7).

Chapter 19 introduced the concept of active management of environmental water, which requires environmental water organizations to choose how to use environmental water to achieve the best outcomes each year. This flexibility is extremely important for effectiveness and efficiency, but it also requires the decision maker to actively engage with stakeholders and local communities both before and after decisions are made and implemented. Environmental water organizations are getting better at making these decisions transparent, but real legitimacy requires expanding the sphere of influence, so that local communities are invested in making the best decisions for environmental water in their local context. By focusing on both input (the process) and output (the outcome) legitimacy, environmental water policy makers and practitioners can embed legitimacy throughout the environmental water management process.

To facilitate the adoption of legitimacy as a measure of success, there are two foci for potential future activity. First, we should build a database of demonstration catchments that show how legitimacy has (or has not) been embedded and resourced throughout environmental water programs. Despite the continuing challenges of implementation, environmental water programs are now sufficiently widespread and diverse that the capacity for collective learning is enormous (see Chapter 25). Second, where environmental water programs are already underway, policy makers and practitioners need to actively include legitimacy as a measure of success, and report on both input and output legitimacy. There are many ways to monitor and report on legitimacy. A starting point might be using indicators such as media articles (positive and negative), and short surveys to report stakeholder numbers, diversity of stakeholder groups, and to gauge the opinions of stakeholders involved in the ongoing program.

27.7 CAN ADAPTIVE MANAGEMENT BECOME STANDARD PRACTICE?

Adaptive management centers on the concept of iterative learning resulting in improvements in management (Allan and Stankey, 2009; Pahl-Wostl et al., 2007). It is essential in situations where management decisions must be made under uncertainty. Under the umbrella of adaptive management, there is the simple approach of *learning by doing* through to more complex and rigorous processes involving management experiments and sophisticated ecological response models (Allan and Stankey, 2009). Adaptive management is particularly well suited to problems such as environmental water management where the outcomes are responsive to management decisions, but there is uncertainty about the outcomes of alternative decisions (Williams and Brown, 2014). There are multiple sources of uncertainty affecting environmental water management, including climatic uncertainty affecting future water availability and demands for consumptive use, and scientific uncertainty concerning ecological responses to changing patterns of flow variability (see Chapter 15). Despite the well-recognized potential benefits of adaptive management, few successful examples have been reported (see Chapter 25), although the extent to which this reflects limited successes or simply limited formal assessment and reporting of successes is unclear (Allan and Watts, in review). There are a number of particular challenges that need to be considered to support adaptive management becoming standard practice within environmental water management.

First, and perhaps the most significant challenge for adaptive management, is establishing the legitimacy of the environmental water program, including both social and institutional settings that allow for both success and failures, include a focus on learning, and provide the necessary funds to support the effort (Poff et al., 2003). Providing such institutional arrangements will be essential to the success of adaptive management (Ladson, 2009). One of the key benefits of adaptive management is its potential to facilitate learning through a structured dialogue between scientists and managers (Ladson, 2009; Pahl-Wostl et al., 2007). There has been significant progress in the uptake of knowledge from scientific literature into environmental flows assessment methods (see Chapter 11—14); however, there remains some distance between the growing body of scientific research and translation of this knowledge to address the information needs of managers (Acreman, 2005; Williams and Brown, 2014, 2016). Achieving the full benefit of adaptive management will require novel collaborative arrangements between scientists and managers, as well as with other stakeholders, including local communities, to better incorporate a range of knowledge bodies into management processes (Vietz et al., in review).

Second, documentation of hypotheses, decisions, and outcomes of adaptive management must be improved to facilitate learning and knowledge transfer across catchments. Chapter 25 recommends the inclusion of *reflectors* in adaptive management teams to document and disseminate learnings, and Allan and Stankey (2009) suggest "careful documentation processes" is one of the core elements of successful adaptive management. This requires a documented hypothesis or predictive model that links alternative management actions to management objectives, which in the case of environmental water requirements, links flow decisions to environmental objectives (Allan and Stankey, 2009; Williams and Brown, 2014). The model need not be numeric; it could even take the form of a list of predictions under different management options (i.e., suggested as an option in ELOHA; Poff et al., 2010). The documentation of the predictions, not so much how they are arrived at, is the important aspect. This documented model, complete with its inherent uncertainties, plays an essential role in presenting researchers' and managers' understanding of how a system behaves, and in building consensus and shared understanding among those involved in the management process (Beven and Alcock, 2012; Liebman, 1976). There has been considerable growth in the number of scientific publications examining the environmental effects of flow alteration (Poff and Zimmerman, 2010; Stewardson and Webb, 2010; Webb et al., 2013); however, the challenges of linking this scientific knowledge to management decisions are considerable (Acreman, 2005). In the case of environmental flows assessments, while there are methods that support transparent empirically based frameworks (i.e., ELOHA and DRIFT), the majority of environmental water regime recommendations and many management decisions are currently based on expert judgments that draw from the experts' cumulative experience and understanding of current literature (Stewardson and Webb, 2010). Often there is an implicit conceptual model that captures the causal pathways that underlie these expert judgments, but this is rarely documented as part of the decision-making process. The explicit representation of such models is a crucial element of adaptive management of environmental water, and one that is particularly important for active environmental water management.

Finally, monitoring and evaluation is an essential element of adaptive management, but traditional agency-led programs are time-consuming and expensive (Williams and Brown, 2014). Without monitoring, there can be no adaptive learning, no way to complete the adaptive management cycle, and no way to update future management in the light of new knowledge. One reason identified for the failure of adaptive management is the unfortunately common lack of commitment to monitoring by management agencies (Schreiber et al., 2004). These monitoring programs need to support both the inner and outer adaptive management loops (see Chapter 25) of short-term implementation and long-term planning. Effective monitoring can help to demonstrate the benefits of providing environmental water (enhancing legitimacy), and can also add to the growing knowledge around ecological responses with flow (see Chapter 25). The design, funding, and administration of such monitoring programs needs to be identified as early as possible, and a commitment made to long-term engagement (Davies et al., 2014). Citizen science efforts at developing models and monitoring their outcomes could further enhance the potential of intelligence gathering, dissemination, and learning to underpin effective adaptive management (e.g., Liu et al., 2014). Exploring options to enhance the resourcing, local support, and implementation of monitoring has the potential to allow adaptive management to occur in places where the monitoring cost may otherwise be prohibitive.

27.8 CONCLUSION

> *Clearly, on-the-ground implementation of policy aspirations is the foremost global challenge to achieving environmental flows.*
>
> **Le Quesne et al. (2010)**

There has been significant progress in environmental water management across the globe as evidenced by the increasing scientific knowledge and the number of countries that now recognize environmental water in their policies and legislation. Despite this progress, there remains a persisting implementation challenge, even as the need for political will and renewed policy commitments and resources becomes increasingly urgent. It is difficult to assess the progress and remaining challenges, as there is no central repository of information on the level of environmental water regime implementation across the globe. Moving forward, a benchmarking study would allow greater assessment of progress and improve opportunities to share and coordinate across regions.

There is, however, a range of examples of successful environmental water management and ongoing research into the challenges of environmental water management as highlighted throughout this book. There are great opportunities to build on this experience through better mechanisms to translate this knowledge across geographies and policy settings. One possible approach is to establish living labs as a means to communicate science, management tools, and social engagement strategies that have been successful (or unsuccessful!), and the journey of implementation over time. An important aspect of making the knowledge and tools gained at living labs transferrable is to develop a consistent framework and language.

There is an inherent trade-off in the implementation of environmental water management between pragmatism and efficiency on the one hand, and aiming for the *best case solution*. Indeed, in writing this chapter it was apparent that different authors have different opinions on the correct balance. In reality, this is a location-specific question. It is important to recognize that in those countries where environmental water regimes have been implemented, it has often been a lengthy and iterative process. Whatever the first step is (be it a precautionary and readily implemented option, or a well-researched and consultative option), the process should allow for learning and changes over time. These changes may be in response to changing social values, changing climate, or new knowledge. A key aspect of adaptive environmental water management will be ensuring that suitable institutional and governance arrangements are in place, and that the program maintains (or establishes) legitimacy. This is an aspect of environmental water management that still requires research and demonstration in the field. Importantly, getting the institutional and governance arrangements right will ensure ongoing funding and community support for an environmental water program (Pahl-Wostl et al., 2013).

This book has provided an overview of the complete environmental water management process—*from policy and science to implementation and management*. In this final chapter, we have highlighted some of the reoccurring themes throughout the book and discussed these in terms of the ongoing implementation challenge. Many of these challenges are not technical in nature, but rather related to concepts of engagement, partnership, legitimacy, sharing of knowledge, and enabling institutional structures. This highlights the importance of Ostrom's (1990) concepts of engagement and social agreements (as introduced in Chapter 1), and provides a positive lens to work through toward the sustainable management of our water resources.

The most powerful force ever known on this planet is human cooperation—a force for construction and destruction.

Jonathan Haidt (2012)

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