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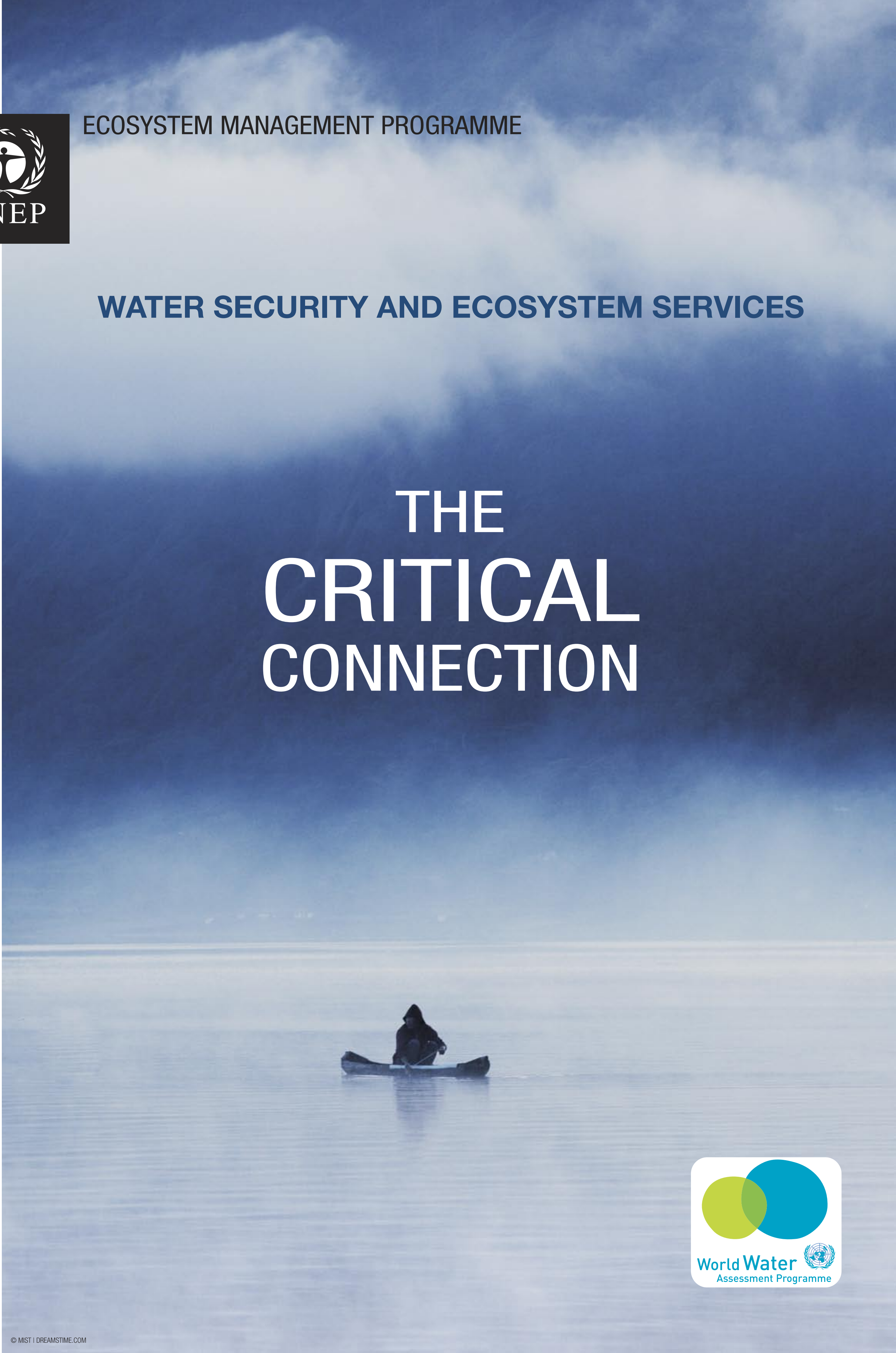
ECOSYSTEM MANAGEMENT PROGRAMME

A CONTRIBUTION TO THE UNITED NATIONS WORLD WATER ASSESSMENT PROGRAMME

WATER SECURITY AND ECOSYSTEM SERVICES

THE CRITICAL CONNECTION



World Water Assessment Programme

Water security and ecosystem services:

The critical connection

A Contribution to the United Nations
World Water Assessment Programme (WWAP)

United Nations Environment Programme
Nairobi, Kenya
March, 2009

ACKNOWLEDGEMENTS

This document represents the collective expertise of a diverse group of individuals concerned with ecosystem degradation, and the continuing loss of the services provided by these ecosystems. Attention is given to aquatic ecosystems because of water`s fundamental role as the `blood` of ecosystem structure and functions, and an engine of economic production. These characteristics make the goal of maintaining ecosystem services and water security a complementary and overlapping task. It is hoped the contents of this report, which was developed as a contribution to the 3rd World Water Development Report, will facilitate more in-depth discussion on these important life-supporting topics.

In view of the importance of water security in supporting human survival and economic livelihoods, as well as water needs of the ecosystems providing these services, the efforts of the Working Group in preparing this report are gratefully acknowledged. Their hard work and insightful contributions to this effort were the primary reason for its completion. These individuals, listed alphabetically, include Gunilla Björklund (Sweden), Marti Colley (Panama), Mogens Dyhr-Nielsen (Denmark), Mohan Kodarkar (India), Hillary Masundire (Botswana) and Jeffrey Thornton (USA). The advice offered by David Coates (Convention on Biological Diversity), David Molden (IWMI) and David Tickner (IUCN) in regard to the content and form of this report is also gratefully acknowledged. The enormous contribution of Walter Rast under tight timeframes is highly appreciated, having ably put the publication together in this form. The enormous contribution of Walter Rast, who put the publication together under tight timeframes, is highly appreciated. The many valuable comments and suggestions provided by a range of reviewers, both within and outside the UNEP family, are also greatly appreciated, as is the last-minute editing and design work by Peter Hulm and Nikki Meith.

The hard work and perseverance of all these individuals made the preparation of this report possible, and sincere thanks go to all of them.

FOREWORD

We live in a world of ecosystems – and our existence would not be possible without the life-supporting services they provide. Properly-functioning ecosystems in turn are fundamentally related to water security. This report, although brief in content, is meant to serve as food for thought about the linkages and interactions between human survival and well-being, and about the ecosystem services and water security that result from these linkages and interactions. This complex topic requires discussion at many levels of government, society and science. Continuing experience around the world, however, highlights the fact that water security and ecosystem services must be viewed with the same degree of importance in national development programmes as do social welfare and economic growth. These considerations are also relevant to achieving the targets outlined in the Millennium Development Goals (MDGs). Unfortunately, however, the results of the Millennium Ecosystem Assessment clearly illustrate that we are failing to recognize these linkages and ensure their sustainability. Instead, humanity is continuing to overexploit and pollute ecosystems throughout the world, and at all scales.

This report makes the link between sustainable development and ecosystem services, highlighting that the former is not possible without the latter. Economic development in turn requires an adequate natural resources base, and humans are constantly engaged in activities to access these resources. The dilemma is that the activities involved in accessing and using these resources, although directed to beneficial uses, also have the potential to negatively impact the very ecosystems that provide them in the first place. Thus, activities that result in ecosystem degradation can be significant constraints to sustainable development.

The role of water security in addressing ecosystem sustainability is fundamental to this goal. As discussed in this report, continued provision of ecosystem services for human welfare and economic development is dependent on properly-functioning and sustainable ecosystem services. Further, water security is at the core of sustainable ecosystem management,.. The dual goal of ecosystem sustainability and water security must be pursued vigorously and in a timely manner, since it could take decades before we master the political, institutional and technical aspects that enable humanity to use the full potential of ecosystem management for water security. This report is meant to highlight this reality, and to provide examples of cases in which various measures were used to facilitate ecosystem sustainability and water security. Although only providing a brief discussion of these important issues, it is hoped this report will provide the impetus necessary for governments, non-governmental organizations, industry, agriculture and other ecosystem services stakeholders to consider such issues in addressing both our short-term needs and our long-term goals.

Achim Steiner
Under Secretary General of the United Nations
and Executive Director of UNEP

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CHAPTER ONE

Introduction

Sustainable development and human well-being

Sustainable economic development has become an encompassing goal of the international community, and at the national level, as a means of improving the health and well-being of citizens over the long term. Achieving sustainable development at any level, however, remains a daunting task, and underpins the targets identified in the Millennium Development Goals. These targets are many and diverse, addressing basic human health issues such as hunger, poverty, education and health. At the same time, however, these targets are also directly or implicitly related to the health and sustainability of our ecosystems, upon which the target of sustainable development rests. Many factors, including scarce financial and human resources, fragmented authority and responsibility, and lack of political will, remain formidable obstacles to sustainable development. The greatest impediment to achieving sustainable development, however, is depletion and degradation of natural resources, which represent the essential ingredients for human survival, and the 'fuel' and building blocks for human well-being and economic development. The long-term sustainability of ecosystems is critical, therefore, since they are the ultimate source of these resources.

Ecosystem services and the Millennium Ecosystem Assessment

We live in a world of ecosystems. Simply stated, an ecosystem is a complex of living organisms (plants, animals, microorganisms) and their non-living surroundings (water, soil, minerals). These living (including humans) and non-living components are linked as a functional unit by an incredibly complex series of interactions and processes that impact the status of both groups of components. Further, ecosystems provide a range of services to humans, including provisioning, regulating, supporting and cultural, *There is virtually no place on our planet isolated from the potential impacts of human activities.*

without which our survival and well-being would simply not be possible.

This document was developed as a follow-up to address the findings of the Millennium Ecosystem Assessment (MA). The MA, begun in June 2001, was a four-year international work programme to provide decision-makers with scientific information on the links between ecosystem changes and the well-being of humans. An ideal economic development scenario would be one in which humanity interacted with ecosystems with the guiding principle that of sustaining their services rather than presiding over their continuing degradation. It also would include recognition of the inseparable connections between humans and ecosystems. The interactions between humans and the ecosystems that surround them control their health and vitality. Unfortunately, however, the MA reported that 60% of the ecosystem services accessed are in decline, with the main drivers of this decline being anthropogenic in nature. More precisely, it is human-environment interactions that result in the greatest disturbances or imbalances in the structure or function of ecosystems.

It is easy to say that we must take care of our ecosystems. Experience from around the world, however, clearly indicates that we continue to degrade or over-exploit ecosystems to meet our natural resource needs, whether by the very poor to meet simple survival needs or by the more affluent to satisfy an increasing appetite for material goods. There is virtually no place on our planet isolated from the potential impacts of human activities. Climate change, for example, is a global-scale phenomenon affecting our entire world.

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Persistent synthetic organic pollutants exist in measurable quantities in the fatty tissues of seals and other organisms at the earth's poles. Pollutants from industrial activities in one location can travel long distances from their source to impact ecosystems in other locations. Examples of human use (and misuse) of our natural capital (resources) abound, including polluted rivers, lakes and wetlands, depleted groundwater aquifers, erosion and loss of productive land, deforestation, desertification, decreased biological diversity, etc.

The drivers of environmental degradation and over-exploitation are numerous, multifaceted and synergistic in impact. As highlighted in the 3rd World Water Development Report, many important environmental drivers actually exist outside the domain of 'the environment'. As examples, significant environmental change drivers include population growth and human migration from one location to another, resulting in a range of environmental stresses. Social drivers range from activities of the very poor to meet simple survival needs, to unsustainable production and consumption patterns in developed nations, both with their related environmental stresses. Technological advances represent a double-edged sword in that they can be rapid in application and impact. An example is improved water conservation, processing and re-use technology, as well as increased agricultural and industrial productivity associated with existing water resources.

On the other hand, the emergence of biofuels has led to an unanticipated use of water resources for crop production, with consequences for grain production patterns and water resource needs. Laws, policies and institutions represent governance elements, whether directed at environmental issues in general, or water security in particular. Further, climate change represents a global-scale consequence of human actions, attributed by many to the impacts of the excessive and unsustainable use of fossil fuels for transportation and energy production. In fact, humans can claim to be the most 'successful' species on our planet in that they are the most capable of significantly changing the natural environment by engaging in activities to meet their resource needs. This is the basis for some to view the environment as something to be conquered to meet human needs, in contrast to the role of humans as stewards of the environment, ensuring its sustainable use (Brinkman and Pedersen, 2000).

Human survival is completely dependent upon the continued flow of ecosystem services. Some countries have the resources, both human and financial, and technology to address the immediate impacts of ecosystem changes. These resources are not infinite, however, and their utilization comes with an environmental price tag, substantial in some cases. Over-exploitation (depletion of supply) and degradation (depletion of quality) are two aspects of the price to pay, with the causes ranging from economic growth to demographic changes, and even individual choices. Thus, recognition of the limits of nature to provide these services at the pace needed to meet human demands is critical, although often ignored or subordinated, in national economic development plans and programs.

The nature of ecosystem services

Ecosystem services represent the benefits that humans obtain from ecosystems. These services are both direct and indirect in nature, some easily recognized and others more subtle. And human well-being is fundamentally dependent upon all these services. As noted in the MA (2003), changes in these services can affect humanity, sometimes dramatically, with negative impacts on security, basic materials for human health and well-being, and the maintenance of social and cultural relations.

... humans have changed ecosystems more rapidly and more extensively during the past half-century than ever before in human existence.

By way of illustration (Figure 1), ecosystem **provisioning** services encompass the products obtained from ecosystems, including food, freshwater, timber and fuel wood, fibres and genetic resources, while non-material benefits obtained from ecosystems comprise **cultural** services, including recreation, transport, ecotourism, spiritual, religious and aesthetic uses, education, cultural heritage, and a 'sense of place. Ecosystem **regulation** services includes the benefits to be derived from the role of the environment in climate regulation, flood alleviation, water purification, and disease regulation. **supporting** services underlie the sustainability of all the above-noted services, including nutrient cycling, soil formation and primary production.

The MA assessed ecosystem changes within the context of several determinants and constituents of human well-being. These include: (1) ***security*** – referring to the strength of the social structure of a community, and to its material well-being, both of which can be influenced by changes

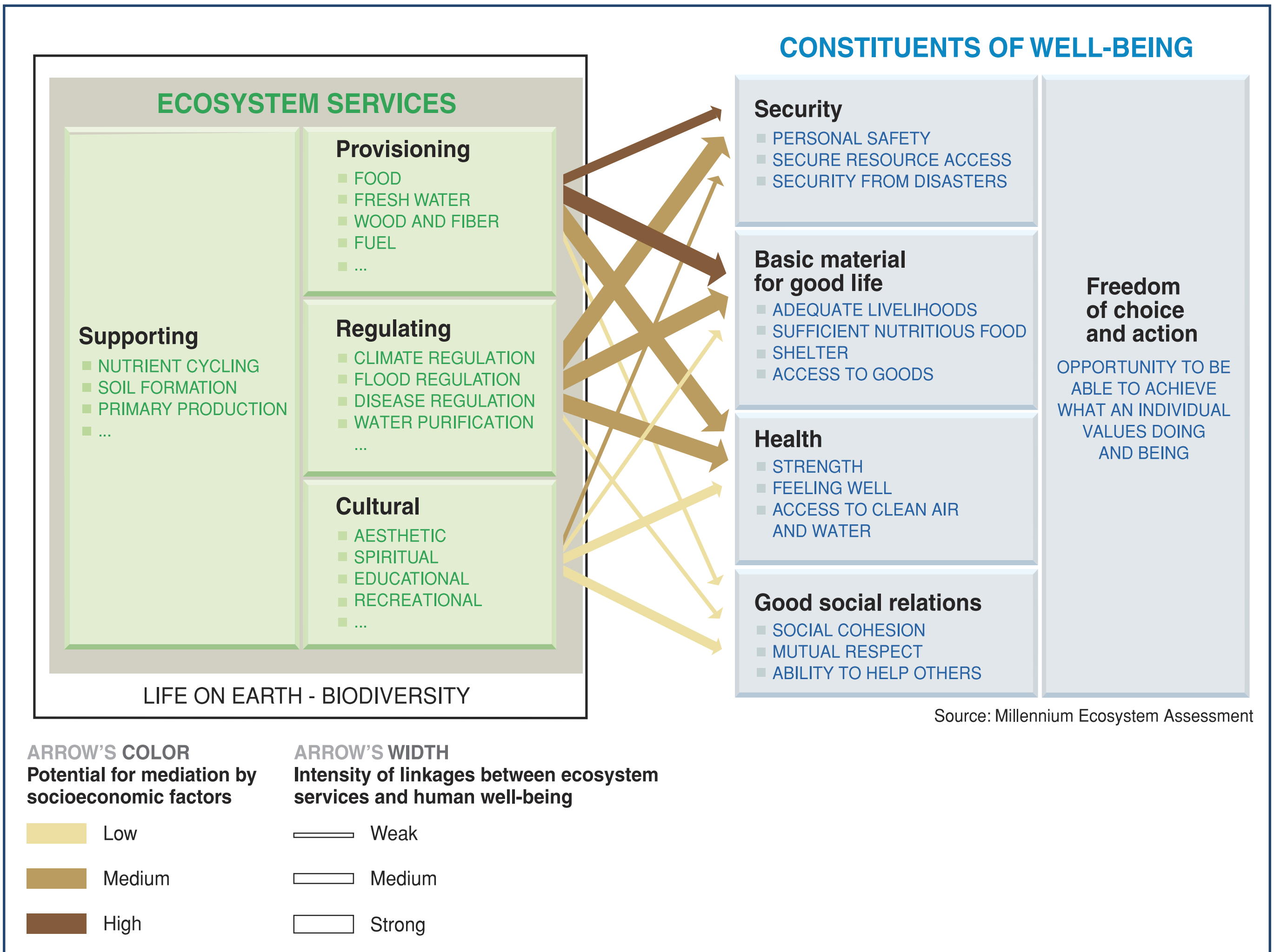


Figure 1. Linkages between ecosystem services and human well-being.

in provisioning and cultural services; (2) ***basic material for human well-being*** – which can be influenced both by provisioning (food, fibre, etc.) and regulating services such as water purification; (3) ***human health*** – which is influenced both by provisioning services (food production), regulating services, particularly those that can influence the distribution of disease vectors, pathogens, etc., and also cultural services such as spiritual benefits and recreation; and (4) ***social relations*** – the quality of human experiences, influenced primarily by the cultural services. All these determinants are underpinned by so-called '***freedoms and choices***,' which can be influenced by changes in all the above-noted services (MA, 2003).

The range of services provided by different ecosystems is illustrated in Figure 2, which also highlights the distinction on one hand, and the continuity on the other hand, of these services (MA, 2005b). Although these services are not routinely valued or costed in financial terms, their estimated cumulative economic value on a global scale is enormous.

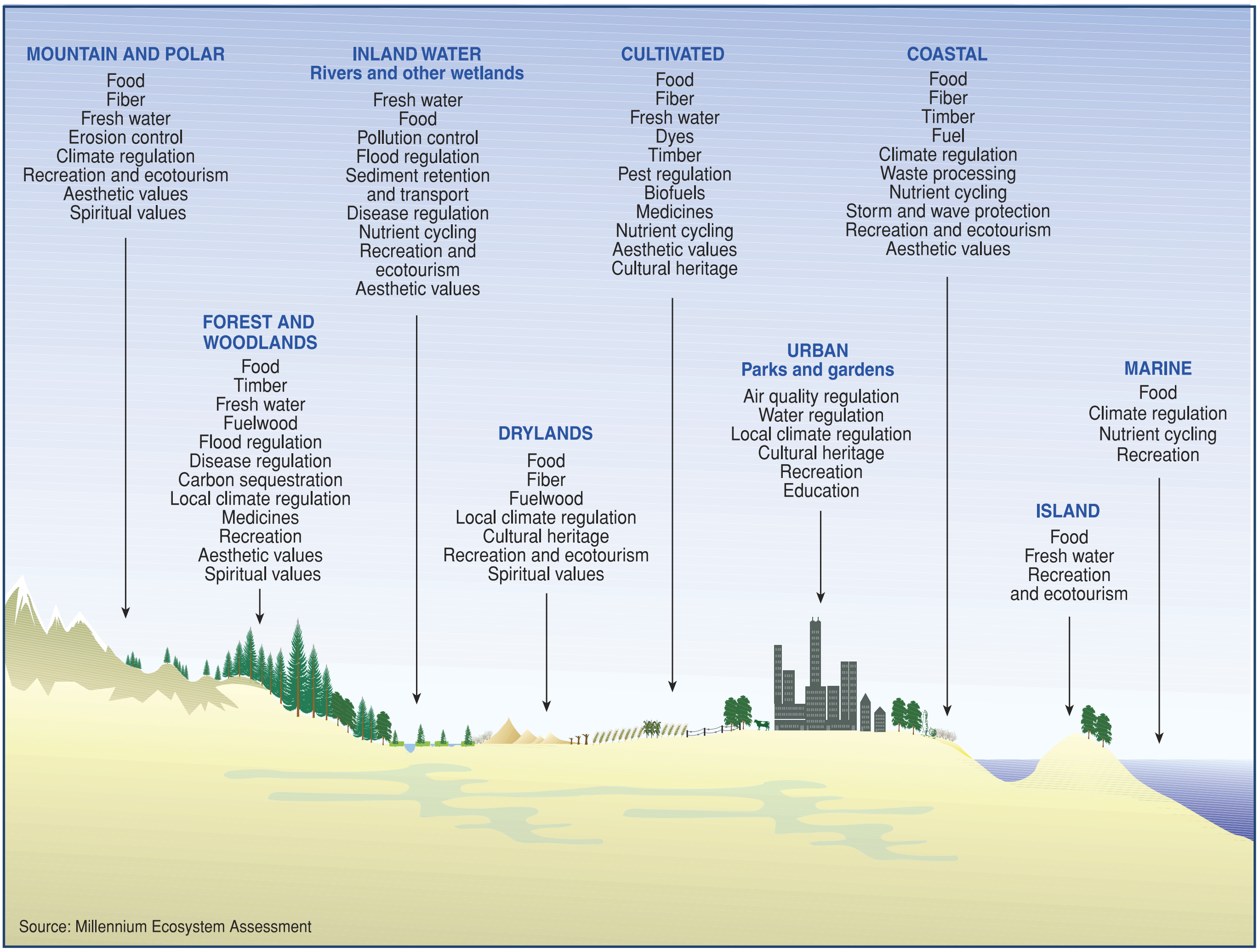


Figure 2. Ecosystems and their representative ecosystem services

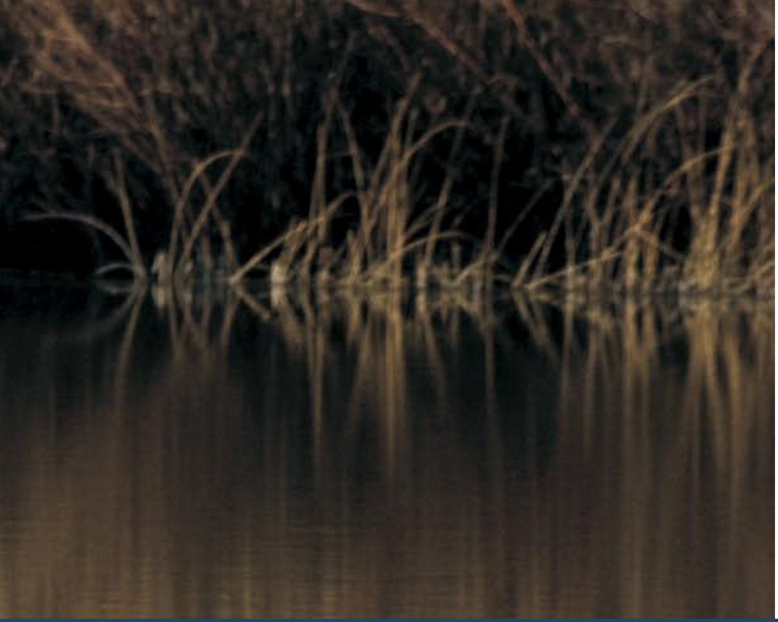
... demand for ecosystem services around the world is now so great that trade-offs between ecosystem services ... are becoming increasingly necessary.

In an often-cited example, Costanza et al. (1997) provided an estimate of the value of the world's ecosystem services and natural capital, and the benefits to be derived from them. Based on their work, the estimated economic value of 17 ecosystem services provided by 16 biomes averaged US$ 33 trillion per year. The aquatic biomes examined in their study (both marine and freshwater) made up about US$ 27 trillion of this total estimate. This compares to a total GDP, of all the countries in the world combined, of approximately US $17 trillion during the study period. Although some assumptions used in determining the economic value of specific ecosystem services in the study have been questioned, there is no doubt that the total value of ecosystem services provided to humanity totals in the tens of trillions of dollars annually.

Against this background, the MA reached a number of important conclusions regarding ecosystem changes on a global scale, many with distressing long-term implications (MA, 2005a). Fifteen (60%) of the 24 ecosystem services examined in the MA are being used in an unsustainable manner, resulting in pollution, degradation and over-exploitation. Further, human-induced ecosystem changes are increasing the possibility of non-linear changes in ecosystems (e.g., accelerating or reversing trends) with potentially significant consequences regarding their ability to provide life-supporting ecosystem services to humanity. This observation highlights the great responsibility of natural resource managers to secure the resilience of ecosystems.

In addition, to meet growing demands for freshwater, food, fibre, fuel, etc., humans have changed ecosystems more rapidly and more extensively during the past half-century than ever before. Although these changes have contributed to human well-being and economic development, they also have resulted in substantial ecosystem degradation in many locations. They have reduced global biodiversity, as well as exacerbated the poverty of some groups of people, particularly the rural poor who often depend directly on ecosystem services for their economic survival and livelihoods.

Even more significant was the conclusion that the demand for ecosystem services around the world is now so great that trade-offs between ecosystem services (e.g., conversion of forests to agricultural land, with attendant gains in some ecosystem services at the expense of perhaps even more important supporting or regulating services) are becoming increasingly necessary. Assuming a continuing trend in this direction, the MA concludes that future generations will experience a substantial reduction in the human benefits to be derived from these ecosystem services. It also means that future efforts may have to be directed to balancing between ecosystem services in some locations and under some circumstances, particularly when they are being overexploited or degraded.



CHAPTER TWO

The ecosystem approach and water security

Freshwater resources and human impacts

Of all the resources required for sustaining ecosystems and the services they provide for human health and well-being, water is arguably the most important. In contrast to all other resources, no living organism can survive in the complete absence of water, making it an essential ingredient necessary for all life as we know it. The Earth's water resources can be characterized as: (1) finite - there is a fixed quantity on our planet; (ii) sensitive – it can be easily degraded by human activities; and (iii) irreplaceable – it has no substitute in all its uses (Illueca and Rast, 1996). Further, the hydrologic cycle links our planetary components of water, land and the atmosphere via a never-ending pattern of precipitation, runoff, infiltration, and evaporation.

Sustainable utilization of water resources is the primary goal of water resources management. Water resources were initially viewed primarily as a commodity to be utilized in the same sense as oil, ore or other extractable resources, with meeting human water needs being the primary concern of water resources managers. Attention focused on obtaining additional water sources when existing supplies became fully allocated or utilized.

This approach was not sustainable, however, since human ability to extract and utilize water resources can easily overwhelm the ability of our ecosystems to provide them in the quantity or quality for which they are being used. Only in recent years, with the development and advocacy of integrated water resources management approaches, have the other fundamentally important roles of water become apparent, particularly the often-ignored need of 'water for nature.' The rationale is that the human-ecosystem linkage regarding water resources is fundamental and irrevocable, and it is within the concept of integrated water resources management that the interdependence of humans, ecosystems and water resources has become most evident.

The top four groups of organisms facing extinction ... are aquatic species.

The results of misusing water resources, and resulting ecosystem degradation and its impacts on ecosystem services, illustrate the negative impacts of non-sustainable water use. Water systems are very sensitive to human activities in their surrounding drainage basins. Lakes, for example, are sinks for inputs of water, and the materials and pollutants carried in it, thereby being sensitive barometers of human activities in their surrounding watersheds (ILBM, 2005). Nor does the concern rest solely with direct human water uses. The top four groups of organisms facing extinction, for example, are aquatic species (WWDR, 2003). Consequently, the degradation or elimination of ecosystem services because of the unsustainable use of ecosystems is usually readily visible where water resources are concerned.

Sustainable ecosystem services and Integrated Water Resources Management (IWRM)

In addition to being an essential requirement for human survival and a fuel for economic development, as the 'life blood' of ecosystem functioning, water is therefore fundamental to sustainable ecosystem services. Water management therefore translates into managing ecosystem services, and must be a fundamental goal of virtually all such efforts.

With this goal in mind, and the need to address the continuing degradation and over-exploitation of aquatic ecosystems, the concept of Integrated Water Resources Management (IWRM) has gained increasing acceptance by water stakeholders and decision-makers, both in the international water arena and on the national level. Touched upon in varying degrees since the 1972 UN Conference on the Human Environment, the concept of IWRM was more firmly grasped at the 1992 UN Conference on Environment and Development (United Nations, 1992). Among the water-related observations arising from this 'Earth Summit,' convened to adopt the principles for sustainability action in the 21st century known as Agenda 21, was the recognition that the degree to which human social well-being and economic productivity was dependent upon development of water resources was often not appreciated. Further, it was concluded that a holistic approach to water management was of "paramount importance for action in the 1990s and beyond". This conclusion included recognition of freshwater as a finite and vulnerable resource, and the need to integrate the water plans and programs of different water-use sectors into social and economic policies on a national scale. In the freshwater chapter of Agenda 21, the governments defined IWRM as a process based on water being "an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization." The Global Water Partnership (GWP, 2000) provided a more operational definition of IWRM as a methodology that promotes the coordinated development and management of water, land and related resources in order to "maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." IWRM views watersheds in a comprehensive manner – within the context of their geographic position in the landscape, and the entirety of their human influences and ecosystem functions.

The integrated approach embodied within the concept of IWRM marks a fundamental departure from the perspective of water as a commodity, to one that considers all major water uses on an equal basis, including the water needs of nature. It collectively considers both the scientific and technical elements of water management (e.g., water quantity and quality; geology; physiography and topography; flora; fauna; water supply and demands), and the socioeconomic components (often referred to as water governance, and including such elements as institutions, regulations, policy, public awareness, financial concerns, cultural values, political realities, etc.). The distinction between these two groupings is that the former fundamentally define and describe the quantity, quality and location of water resources (*what; where*), while the latter represent elements that fundamentally control or define *how and why* humans use their water resources. Although more qualitative in nature, and more difficult to identify and assess, these latter elements are fundamentally important in developing and implementing sustainable water management programs. The International Lake Environment Committee (ILEC, 2005) also evaluated the importance and interrelations of the scientific and socioeconomic elements within the latter elements within the context of integrated lake basin management (ILBM).

As promulgated by the Global Water Partnership (GWP, 2000), IWRM focuses on three main goals, including: (i) maximizing *economic efficiency in water use in response to increasing water demands*; (ii) *equity* in the basic access of people to water resources; and (iii) *environmental and ecological sustainability*, which translates into managing water systems so as not to undermine their ecosystem services. Achieving these goals requires, among other elements: (i) a general enabling framework comprising policies, legislation, regulations and information; (ii) institutional roles and functions of various administrative levels and stakeholders; and (iii) operational management instruments for regulating, monitoring and enforcement for decision-makers. The cross-sectoral integration of these elements as they relate to various water needs also was stressed, including water for maintaining ecosystem services (e.g., "water for nature" in Figure 3).

Many governments and agencies have struggled to effectively implement IWRM for water systems around the world. This difficulty is attributable to the many complex scientific, socioeconomic and financial elements to be simultaneously considered with this approach. Nevertheless, the desirability of an integrated water resources management approach was highlighted at the 2002 Johannesburg World Summit on Sustainable Development, with the request that countries develop IWRM-based 'water efficiency plans' as a means of facilitating the management of their freshwater resources for sustainable use. The Global Water Partnership (2004, 2006) subsequently provided two interim reports on the progress of this effort. UN-Water (2008) subsequently completed a more comprehensive status report on IWRM plans on a global scale for the 16th Session of the Commission on Sustainable Development. Although these efforts have indicated mixed results to some degree, the overall indications are that this request is being seriously pursued by governments in many countries around the world.

The scientific literature contains many examples of the use of economic instruments, institutional and policy reforms, political structures, etc., to address human uses of water resources. A continuing concern of many, however, is that although considerable attention has been given to

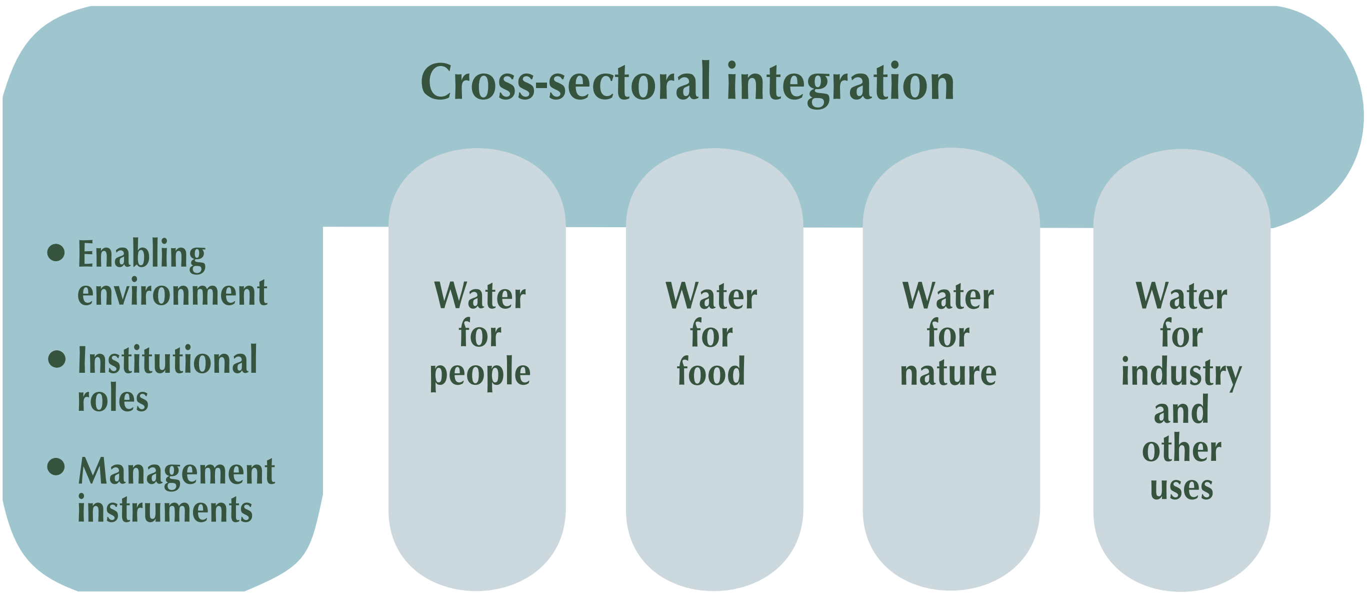


Figure 3. Integrated Water Resources Management (IWRM) and its cross-sectoral integration. (Source: GWP 2000)

... every time we access, develop, transport or utilize water resources, we leave an impact that may degrade the service provided by the river, lake, wetland or groundwater aquifer that supplied the water in the first place.

human water needs for drinking water and sanitation, food production and industry (Figure 3), less attention has been given to the 'environmental and ecological sustainability' element, the ultimate focus of which is sustainable ecosystem services. On the basis of the previous discussion of the foundational role of ecosystem services in supporting human life and well-being, it could readily be argued that if the environmental components providing ecosystem services are not maintained or are degraded by human activities, the existence of the entire water sub-sector structure is at risk. Thus, the need to effectively manage ecosystems and their services has far-reaching implications for human health, well-being and economic stability. Yet, environmental concerns in general, and ecosystem services in particular, are often afterthoughts in economic development, or are not incorporated into development and economic policies until late in the process, if at all, thereby ensuring they are often inadequately addressed. Further complicating the situation is that ecosystem degradation is often an incremental process, with each stage of degradation proceeding at such a rate that small changes can go unnoticed for long periods of time, ultimately culminating in major environmental impacts. Glantz (1999), for example, highlighted the 'creeping' nature of environmental degradation, and particularly the manner in which many problems related to the demise of the Aral Sea became evident.

Current water resources management practices do not consider all relevant ecosystem services, even in those situations in which IWRM is applied. As a result, many management efforts only focus on selected services. One clear conclusion is that IWRM must balance all ecosystem services to be most effective. Further, it must assess mechanisms that consider both present and alternative future ecosystem services, including steps to improve ecosystem resilience and decrease vulnerability, particularly as regards the very poor.

An ecosystem approach to water resources management

Ecosystems and biological diversity (biodiversity) are closely related concepts (MA, 2003). Diversity represents the variability among all living organisms and the range of ecosystems in which they reside, and refers to diversity at a number of scales, including genetic, species and ecosystems. The importance of biodiversity is that many of its products are ecosystem services (e.g., food). Biodiversity changes, therefore, can influence the provision of ecosystem services.

The Earth's ecosystems could not function without adequate supplies of water of suitable quality. However, every time we access, develop, transport or utilize water resources, we leave an impact that may degrade the service provided by the river, lake, wetland or groundwater aquifer that supplied the water in the first place. Water security, therefore, depends on how well we can address disturbances to these water systems which can, in turn, affect their services.

Because the notion of an ecosystem represents a useful framework to consider the many linkages between humans and their environment, a so-called 'ecosystem approach' has been advocated by many organizations and individuals as a means of addressing the interrelations between water, land, air, and all living organisms, and encompassing ecosystems and their services. This concept was previously advocated, for example, by the International Joint Commission to the governments of the United States and Canada within the context of the 1978 Great Lakes Water Quality Agreement, as a means of restoring and maintaining the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem (Great Lakes Research Advisory Board, 1978). Used in varying ways by others in the interim, the ecosystem approach was formally proposed in 2000 by the 5th Conference of Parties to the Convention of Biological Diversity as a "strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way". The conservation of ecosystem structure and function was a priority of this approach, as it was in the MA (2003). The Conference of Parties also provided 12 principles of the ecosystem approach, including the need to understand and manage an ecosystem in an economic context, at appropriate spatial and temporal scales, and in consultation with all relevant sectors of society and scientific disciplines (CBD, 2009). An integrated ecosystem approach is therefore crucial to maintaining both ecosystem health and our own.

Nevertheless, managing ecosystems is complex and difficult. The overriding goal is to maintain ecosystem resilience and functioning in order to ensure sustainable delivery of ecosystem services, taking into account both land and water, and the living resources they support. Because many water managers and agencies often do not consider the value of ecosystem services, the result is degraded ecosystems. Indeed, water management has traditionally focused on specific factors directed more toward individual concerns such as water pollution control, water supply and allocation, and specific targeted water-use sectors, rather than considering them collectively. The value of an ecosystem approach rests in the fact that it focuses on the broader goal of balancing and sustaining ecosystem services as the prerequisite for meeting these (and other) sectoral needs. In doing so, the ecosystem approach complements IWRM as a strategy for the integrated management of not only water, but also the associated land and living resources in a way that maintains ecosystem health and productivity, in balance with sustainable water use by humans. In other words – it links ecosystem service delivery and human needs.

An ecosystem-based management approach can facilitate and integrate actions to meet multiple societal goals, including: (1) finding a balance between different water users and uses; (2) preserving water use opportunities (services); (3) integrating water quantity and quality; and (4) merging aquatic and terrestrial concerns. Thus, managing ecosystem services by ensuring that ecosystems have sufficient water of adequate quality available is the key to achieving both water security and human health and well-being.

Facilitating water security and properly functioning ecosystems

Many environmental management options exist to tackle sustainable ecosystem functioning and services. Although not an exhaustive list, major ecosystem management options and goals include:

- ***Maintaining environmental flows*** – Determining and ensuring minimum water flows, and regulating the timing of the flows, in order to maintain rivers and other

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Continuing evidence of the economic development benefits inherent in sustaining ecosystem services, as well as ensuring the water security required to provide them ... makes it appropriate to take action to develop them.

aquatic ecosystems and their resources and diversity of existing and potential services.

- ***Pollution control*** – Reducing the load of contaminants emanating from point and nonpoint sources, including water reuse and recycling and pollution reduction at the source, as well as preventing the entry of such polluting materials into receiving water systems through nonpoint-source best management practices (e.g., buffer strips; conservation tillage; detention basins; grassed waterways).

- ***Ecohydrology and phytoremediation*** – Using natural hydrology, or the ability of specific aquatic organisms, to reduce the impacts of pollution on aquatic ecosystems, or to reverse the adverse effects of these pollutants.

- ***Habitat rehabilitation*** – Undertaking reconstruction and similar activities to rehabilitate aquatic ecosystems and related natural habitats (e.g., bank reconstruction, artificial wetlands) to preserve or restore a range of ecosystem functions.

- ***Conjunctive use of surface and groundwater*** – Utilizing a combination of surface and groundwater to meet human water demands in a manner that maximizes the sustainable use of both water sources.

- ***Watershed management*** – Utilizing structural or non-structural approaches within the context of IWRM or other management framework designed specifically to prevent or reduce degradation of aquatic ecosystems, or to rehabilitate already-degraded aquatic ecosystems.

- ***Water demand management*** – Implementing policies to control consumer demands for water resources, and specifically managing the distribution of, or access to, water on the basis of needs, including allocating existing water resources according to a hierarchy of neediness, rather than increasing the quantity of available water.

- ***Payment for ecosystem goods and services*** – Employing economic instruments (incentives, penalties, user fees, licenses, etc.) to compensate or otherwise 'pay' for excessive use, or degradation, of ecosystem services, typically applicable to industry and similar water users.

The MA highlighted continuing ecosystem degradation through the world, particularly its significant consequences on the ability of ecosystems to continue to deliver life-supporting services. It also highlighted water systems as being very sensitive to such disruptions.

Ironically, water security also is a unifying element in that it supplies people with drinking water, sanitation, food and fish, industrial resources, energy, transportation and natural aesthetic amenities, all of which depend on maintaining ecosystem health and productivity. Continuing evidence of the economic development benefits inherent in sustaining ecosystem services, as well as ensuring the water security required to provide them – in contrast to the continuing negative impacts of not considering these concepts – makes it appropriate to take action to develop them.

To this end, governments and other relevant organizations take all necessary action to ensure ecosystem services and water security – even if done step-by-step, and we learn through trial and error.

The primary lessons learned from our management of water-related ecosystems to date are that:

- ***Continued provision of ecosystem services for human welfare is dependent on sustainable and properly functioning ecosystems; and***

- ***Water security is at the core of management of sustainable ecosystems.***

The next chapter provides case studies of various programmes and activities undertaken to address specific ecosystem degradation issues, with the goal of restoring degraded or damaged ecosystem services. Although not all were undertaken within the larger framework of IWRM, they provide examples showing that properly-functioning ecosystems, and the services they provide, remain central to human society on a local, national and even regional scale.

CHAPTER THREE

Water security and ecosystem services case studies: lessons learned

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Introduction

All ecosystems are impacted in one way or another when they are utilized to meet human needs (e.g., water supply, food production). The concern is whether or not these impacts are sufficient to overwhelm the ability of an ecosystem to continue to provide such services in a sustainable and balanced manner, or to provide different ecosystem services as communities and countries continue to change and develop. This chapter provides summaries of aquatic ecosystem management case studies in different locations in the world (Figure 4). In presenting these summaries, it is acknowledged that IWRM is still being developed and refined, and we are continuing to learn how to better apply it in different locations, contexts and conditions. The case study summaries in this chapter are meant to illustrate the potential of supporting IWRM with the use of an ecosystem approach for water management.

These case study summaries illustrate how ecosystem services were valued in specific cases, and demonstrate that it is possible to restore degraded ecosystems and the diversity of services they provide, within the context of sustainable management of water resources. The examples range from largely technical and technological approaches to socioeconomic approaches, and encompass both developed and developing nations. Based on the case studies provided by the identified authors, each summary highlights: (i) the ecosystem being addressed and the services they provide; (ii) the constraints to their sustainable use and the impacts of these constraints; (iii) the actions taken to ensure ecosystem structure and functioning; and (iv) the results of the actions taken within the context of sustainable ecosystem services and water security. Although each water system must be viewed within the context of its unique characteristics and problems, and illustrate lessons

... virtually all ecosystems provide multiple services, both for meeting human needs and maintaining other living organisms.

learned in regard to the problems specific to the water system being discussed, these case study summaries also offer general lessons that can be used to facilitate effective management of similar aquatic systems for sustainable use.

Lessons learned from case studies

In discussing the case studies in this section, it is noted that virtually all ecosystems provide multiple services, both for meeting human needs and maintaining other living organisms. The examples presented here, however, may focus on measures taken to address one or only a few of these needs, even though the measures may have been formulated and implemented within the context of more comprehensive management programmes. In this way, the results of specific management activities can be more easily highlighted, and the lessons learned from them more easily identified. The case study summaries are grouped below on the basis of the primary ecosystem management approach being discussed. The full case studies are provided as separate background material to this report.

HABITAT REHABILITATION

1. Aral Sea (Central Asia)

Source: Syr Darya River Contribution to Habitat Rehabilitation in the Northern Aral Sea, contributed by Gunilla Björklund, Akkadia Consulting, Stockholm

The Aral Sea is located in Central Asia in the former Soviet republics of Kazakhstan and Uzbekistan. Formerly the site of a thriving fishing and agricultural industry, a management system was imposed diverting water from the influent Syr Darya and Amu Darya rivers for irrigation of cotton. The quantity of water used for irrigation along the rivers doubled between 1965 and 1986, resulting in serious economic, social and environmental damage. Drinking water supplies became polluted and human health problems increased sharply. The salinity and pollution levels rose dramatically, and the Aral Sea decreased to 10% of its former size. In 1989 the Aral Sea split into a small Northern Aral Sea in the territory of

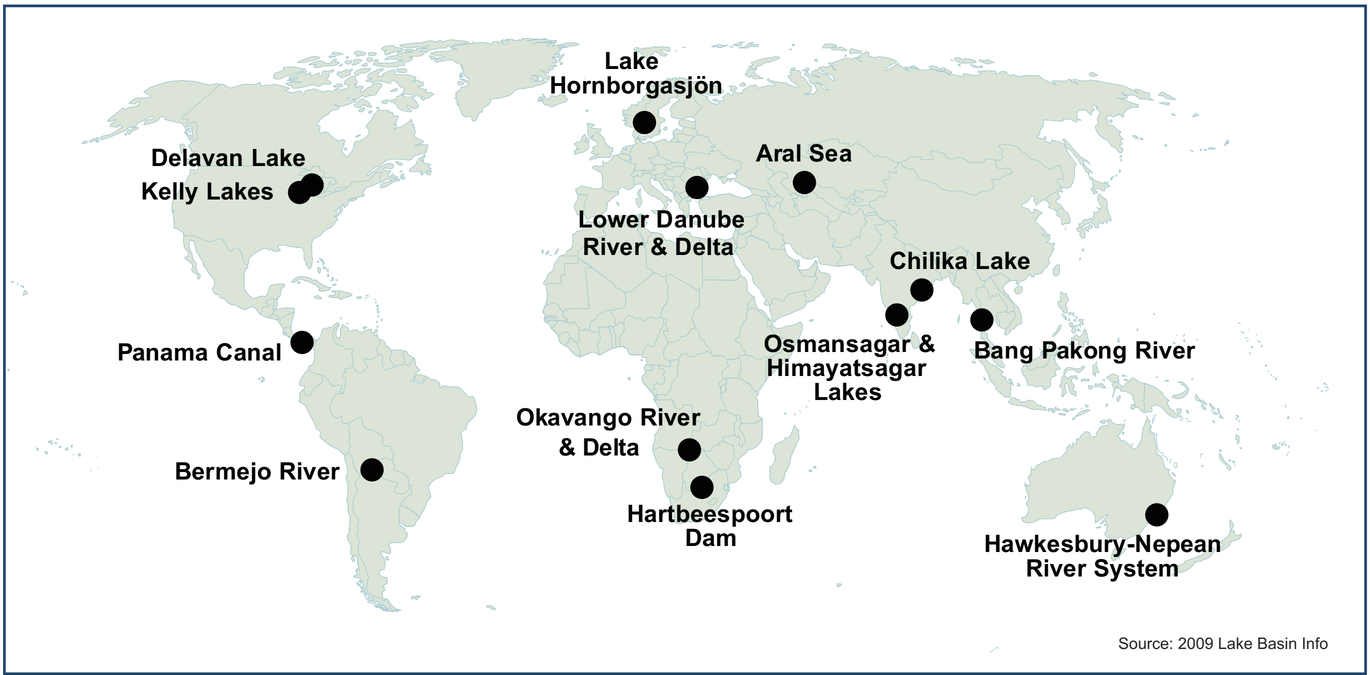

Figure 4. Location of case study water systems

Kazakhstan, and a large Southern Aral Sea in Kazakhstan and Uzbekistan. By 2003, the southern Aral Sea was divided into a deeper Western and a shallower Eastern waterbody, both extremely and increasingly salinized. The ecosystems, including the aquatic ones in the two severely dessicated Southern Aral Sea bodies, and the smaller Northern Aral Sea, as well as the terrestrial ecosystems along the downstream river, became heavily degraded. The salinity of the Southern Aral Sea rose from 14 g/L to more than 100 g/L by 2007, making the water unfit for almost all living organisms. Although the southern bodies of the Aral Sea were considered to be doomed, the smaller, Northern Aral Sea could feasibly be saved.

In early 1990, an earthen dam was constructed to block the flow from the small Northern Aral Sea to the southern parts. Unfortunately, the dam collapsed in 1999, and a World Bank loan was approved subsequently in 2001 for a more substantial construction. Phase 1 of this project was completed in 2008, and a second phase is expected to be agreed to in 2009. The goal of the project is to secure the existence of the Northern Aral Sea, and improve ecological conditions in the area. In addition to the dam, several hydraulic structures were constructed on the Syr Darya to increase it flow capacity, and safely bring much more water than before to the Northern Aral Sea. This would sustain the agricultural and fisheries production in the downstream parts of the Syr Darya basin in Kazakhstan.

Since the project was begun, the water table in the vicinity of the Northern Aral Sea has risen from 37 metres above sea level (masl) to 42 masl, and should continue to increase. The lake area has increased by 18%, and its salinity has steadily decreased from roughly 20 g/L to about 10 g/L . Several fish species have returned in substantial numbers, including the highly-prized pike perch. Reed thickets have cropped up along the banks in the delta area, and are being used by people for animal fodder and house construction.

Lessons learned

Although the long-term prospects for the Northern Aral Sea intervention depend significantly on the sustainability of the ongoing activities, several lessons have become evident in this effort:


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(1) Minimum environmental flows are necessary to rehabilitate the Northern Aral Sea and ensure its ecosystem services.

(2) Adequate quantities of water reaching the downstream parts of the Syr Darya are necessary to ensure the continuity of ecosystem services of the river, as well as its downstream lake.

(3) On the evidence of results to date, management interventions for the Northern Aral Sea must be based on maintenance of a range of long-term ecosystem services, rather than the relatively short-term economic benefits associated with the focused production of cotton in this arid region.

(4) Attempting to achieve sustainable habitat rehabilitation with a focus resting solely on economic benefits, and disregarding the social and economic aspects, is counter-productive, mainly because needed ecosystem services do not only secure habitat rehabilitation, but also serve as a base for a sustainable economic outcome.

(5) Ecosystem rehabilitation measures can be very costly in both environmental and economic terms; prevention continues to be cheaper over the long-term than rehabilitation.

The restored lake ecosystem has facilitated the return of Irrawady dolphins, resulting in community-based ecotourism as an alternative income source for unemployed youth in lakeside communities.

2. Chilika Lake (India)

Source: Chilika Lake, Orissa, India, contributed by Mohan Kodarkar, Indian Association of Aquatic Biologists (IAAB), Hyderabad, India

Chilika Lake is the largest coastal brackish water lagoon in India, situated along its eastern coast. This fragile aquatic ecosystem is known for its amazing biodiversity, being the wintering ground for more than one million migratory birds. The lake is highly productive, with its rich fishery resources sustaining the economic livelihoods of more than 200,000 fishermen, with a long tradition of this activity. Spatial and temporal salinity gradients produced by freshwater inflows from its drainage basin and seawater influxes from the lake mouth into the lake have made Chilika Lake a unique ecosystem, with its fresh, brackish and marine water zones supporting a characteristic biodiversity. The ecosystem and its basin resources also are important to the large agrarian community around the lake. The ecosystem services provided by the lake are plentiful, including: (i) fisheries; (ii) vegetation-based resources (a variety of aquatic weeds are traditionally used for manufacturing handicrafts and other items for daily use (iii) ecotourism (the lake has rich biodiversity, including Irrawadi dolphins (*Orcaella brevirastris*) that have made the lake a major tourist attraction); and (iv) recreational, socioeconomic and religious values (the local communities have a number of traditions and customs that form the basis of the relationship between the lake ecosystems and its surrounding communities).

In the recent past, construction of major hydraulic structures upstream has altered the lake's water flow and sedimentation patterns. Further, sediment transport along the shoreline bordering the Indian Ocean has caused the mouth of the lake to shift and close, thereby affecting tidal water flows into and out of the lake, with profound impacts on its water quality and biodiversity. This loss of hydrologic connection between the lake and the ocean has dramatically altered the salinity and hydrodynamics of the lake, with significant environmental impacts, to the extent that the lake was placed in the Montreux Record (threatened list of Ramsar sites) in 1993. The increased siltation resulting from the lake mouth closure has caused increased turbidity, decreased salinity, encouraged the proliferation of invasive species, and reduced lake surface area. Excessive growths of invasive freshwater weeds and the proliferation of pollution-tolerant fish species with little commercial value have decreased the biodiversity of the lake fisheries, with negative impacts on the economic livelihoods of the fishermen communities surrounding the lake. The introduction of aquaculture by the corporate sector also has impacted traditional fishing, resulting in violent conflicts between aquaculture operators and the fishing communities.

A major step in halting the degradation of the lake ecosystem was the establishment of the Chilika Development Authority (CDA) in 1992. An initial activity was the opening of the lake mouth and creation of a channel through the barrier beach at Satpara in September 2000, which led to the ecological regeneration and restoration of the coastal lake ecosystem. A reduced channel length of 18 km and the resultant de-siltation ensured an exchange of marine and brackish waters which also: (i) improved lake water quality; (ii) restored micro- and macro-habitats of commercially important species; (iii) enhanced lake fishery resources (including fish, prawns and crabs, whose catch improvement is attributed largely to auto-recruitment of fish, prawn and crab juveniles from the sea through the lake mouth); and (iv) controlled invasive species. Six species of threatened fishes and two species of threatened prawns have also recovered to varying degrees. Seagrass meadows have been restored, with an accompanying reduction in numbers of invasive species (e.g., the surface area of freshwater weeds increased from 20 km^2 in 1972 to 523 km^2 in 2000; opening the lake mouth to the sea resulted in a significant increase in weed-free lake surface). The restored lake ecosystem has facilitated the return of Irrawady dolphins, resulting in community-based ecotourism as an alternative income source for unemployed youth in lakeside communities.

Lessons learned

(1) An ecosystem approach to managing ecosystems can restore the ecological health of an ecosystem.

(2) Ecological imbalances can result from both anthropogenic (unsustainable agriculture, pollution, siltation) and natural factors (closure of lagoon mouth to sea);


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(3) Ecosystems can exhibit dramatic improvements if the stresses on them are relieved by management interventions, particularly if the interventions involve stabilization of energy and matter cycles.

(4) An ecosystem-based management approach can restore both macro- and micro-niches (habitats: reeds), dramatically improving ecosystem productivity upon which ecosystem services depend.

(5) Integration of traditional wisdom and involvement of ecosystem-based communities in management efforts holds the key to successful ecosystem management.

(6) If practiced within the ecological limits of an ecosystem, ecotourism has significant potential for generating economic benefits to ecosystem-oriented communities.

3. Lake Hornborgasjön (Sweden)

Source: Lake Hornborgasjön, Sweden: A Eutrophic Lowland Lake, Famous for its Staging Cranes, contributed by Gunilla Björklund, Akkadia Consulting, Stockholm

Lake Hornborgasjön is situated in southwestern Sweden, between the two large lakes Vänern and Vättern. It is a shallow, eutrophic lowland lake of about 150 ha of wetland, surrounded by smaller mountains, forests and agricultural land. The lake was already described during the latter part of the last century as the most perfect waterfowl lake in Sweden. More than 120 different bird species nest and breed in the region. Of particular significance are the cranes, which rest in tens of thousands on their migration north in the spring, that have made the lake famous. Human settlements, dating to the Stone Age, have been found close to the lake. The lake and its wetland area provide food in various ways, being fishing grounds as well as a region for hunting, and cattle grazing. A food shortage during the 19th century was an important, and understandable, driving force to expand agriculture over larger areas, at the expense of wetland areas. Consequently, demands for ecosystem services, specifically to meet human food needs, also increased.

Almost all the wetlands in Sweden have been affected by human activity over the past 200 years, with some drained for conversion to agricultural land. Forests and mires also have been drained to increase forest production. Lake Hornborgasjön was an example of this kind of conversion. The lake's wetland drainage has become so effective that many bird resting and breeding places were nearly or completely eradicated. The water level in Lake Hornborgasjön was lowered five times between 1802 and 1933, with water channelled out of the lake via excavated channels, and the surrounding marshlands subsequently cultivated. This landscape alteration, however, did not generate a significant quantity of new arable land, mainly because the spring floods were still too extensive, and the

Utilizing ecosystem services for agricultural production may not always be more positive than managing for a near-natural ecosystem condition that supports not only agriculture but also tourism and recreational uses.

lake bottom, although dry in summer, remained soft and impossible to cultivate efficiently. As a result, the lake started to become overgrown with shoreline forest, shrubs, sedge and reeds. Its water level decreased to 2.5 m below its level before 1802, with the remainder of the lake being a reed area with some pools. The bioactivity subsequently became imbalanced, being reduced in some areas, and extremely increased in other areas, on a seasonal basis resulting in rapid sedimentation of organic material and a continually overgrown lake.

The first attempts at lake restoration were begun in the 1950s, with the first restoration plan initiated in the latter part of the 1960s. The original restoration plan, approved by the Swedish Parliament in 1977, essentially involved: (i) destruction of reed root mats; (ii) building of embankments at the lake outlet, and at certain low-lying points around the lake, thereby protecting agricultural land close to the lake; and (iii) raising the lake's mean summer water level by about 1.5 m.

The envisaged increase in water level in the 1977 restoration plan of 1.5 m was achieved in the late-1980s. Construction of about 25 km of embankments to prevent flooding of agricultural land was slightly changed, due partly to the costs of their maintenance and potential subsidence problems on soft lake sub-strata. The revisions affected construction of the southeastern and northern edges of the embankments, resulting in shallow shoreline meadows, excellent for waterfowl.

Another positive result was an increased tourism associated with cranes attracted to the wetland area by waste potatoes and barley from a distillery. Several tourist amenities have been created, and the so-called "Crane Dance" is closely followed in the news media.

Lessons learned

(1) Utilizing ecosystem services for agricultural production may not always be more positive than managing for a near-natural ecosystem condition that supports not only agriculture but also tourism and recreational uses.

(2) Restoring a lake to a pre-disturbance condition may result in a more favourable biodiversity, which can generate more income in some situations than agricultural activities.

(3) Ecosystem interactions must be considered within a wider, longer-term perspective when undertaking construction work that impacts the water cycle, since a sustainable ecology may not be achieved, and a second habitat rehabilitation may be needed, if a positive 'impact-chain' cannot be identified as an outcome of such measures.

4. Delavan Lake (USA)

Source: Rehabilitation of Delevan Lake (Wisconsin, USA), contributed by Jeffrey Thornton and T.M. Slawski, Southeastern Wisconsin Regional Planning Commission, Waukesha, Wisconsin USA, and M.E. Eisworth, University of Wisconsin-Whitewater, USA

Delavan Lake is situated on Jackson Creek, which drains through the town of Delavan, Wisconsin, and ultimately to the Mississippi River. The Lake has a surface area of approximately 838.5 ha, a mean and maximum depth of about 6.4 and 17 m, respectively, and a water volume of about 55.3 million m^3. The lake level is augmented by a 2.5 m dam constructed at the lake outlet. Development of the lake began in 1875 with the construction of the first permanent residence along the lake's north shore. Today, the lake serves multiple purposes, ranging from providing a venue for waterfront residential (and limited commercial) development, to providing a popular recreational venue for residents and visitors alike, to being a visual amenity for the community and its visitors.

Delavan Lake historically has experienced various ecosystem impairments, including excessive aquatic plant and algal growths, water quality-related use limitations, and public concerns over its aesthetic degradation. Concerns have been raised regarding deteriorating water quality conditions, the need to protect environmentally sensitive areas, and to prevent the spread of exotic plant species within its basin. To improve the usability of Delavan Lake, and to prevent future deterioration of its natural assets and recreational potential, federal, state, and local agencies began a major, multi-year programme of lake rehabilitation between 1969


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and 1993. The remedial measures were intended to achieve and maintain fishable and swimmable conditions within the lake, and included: (i) formation of a town sanitary district in 1969, and provision of public sanitary sewer service during 1979-1981; (ii) elimination of wastewater discharges from a fertilizer plant on the Jackson Creek Tributary in 1984; (iii) implementation of various agricultural and urban management practices beginning in 1985; (iv) extension of a peninsula in the northeastern part of the lake by about 300 m, modification of the outlet dam and alteration of its operational regime and deepening of the inlet and outlet channels between 1989 and 1990; (v) restoration of a 6-ha wetland, and recreation of a 38-ha shallow marsh and low prairie marsh system, upstream of the lake during 1992, to trap incoming sediment from the Jackson Creek drainage area; (vi) eradication of all fish in the lake during 1989, and subsequent re-introduction of game and forage fish during 1990 and 1991, with densities of piscivorous fish arranged so as to maintain low numbers of planktivorous fish and high numbers of large-bodied zooplankton that are efficient consumers of algae; (vii) prohibition of fishing on the lake through spring of 1992, and subsequent introduction of size limits on all game fish during the angling harvest to maintain a desired predator-prey balance; and (viii) application of aluminum sulfate during April-May 1991, when the lake was drawn down, to facilitate carp eradication.

Such activities resulted in a number of positive outcomes, including: (i) a decrease in total phosphorus concentration from about 0.3 mg/L in 1983 to about 0.1 mg/L in 1991, and to about 0.02 mg/L in the year following alum treatment (although the concentration subsequently increased over time to about 0.05 mg/L); (ii) decreased total phosphorus concentration in the hypolimnion from about 0.4 mg/L in 1990 to about 0.2 mg/L following the alum treatment; (iii) an increase in water transparency (mean Secchi depth) from 1.8 m in 1990 to about 4.25 m following the alum treatment; (iv) a decreased chlorophyll-a concentration from more than 10 µg/L through 1990 (often approaching 30 µg/L) to less than 4 µg/L following the alum treatment, but increasing to more than 10 µg/L in 1999; (v) a shift in aquatic plant populations from bloom-forming blue-green algae to rooted aquatic macrophytes; and (vi) a shift in the fishery from carp and bigmouth buffalo to northern pike and walleyed pike. A related study illustrated that visitors to the Lake Delevan region annually spent about US $9 million, with angler activity alone generating an estimated US$1.38 million per year. The sum of direct and secondary spending as a result of the existence of Delavan Lake was estimated to be between US$ 70–80 million per year, with about 812 jobs generated as a result of these expenditures.

Lessons learned

(1) The Delavan Lake remediation programme resulted in substantial economic benefits to the local community in terms of both property valuations and recreational dollars, which more than offset the community investments in clean water.

(2) The water quality improvement project, although having exceeded the expectations of the management agencies, is nearing the end of its design life, and further interventions may be required in the foreseeable future.

(3) A continuing challenge is to convince the local community that further investments in the lake ecosystem are of value to the community as a whole.

(4) Interventions to rehabilitate ecosystems can be very costly, but ultimately result in enhanced financial benefits, with monitoring being necessary to verify results.

5. Lower Danube River and Danube Delta (Southeast Europe)

Source: Lower Danube River and Danube Delta, contributed by contributed by Gunilla Björklund, Akkadia Consulting, Stockholm)

The Lower Danube is the natural flowing river stretch between Romania and Bulgaria in southeastern Europe. It contains remnants of floodplain forests and many well-preserved wetlands, and ends in the important Danube Delta on the Black Sea. The biggest hydropower dam and reservoir system along the entire Danube River is located at the Djerdap (Iron Gate) gorge, about 200 km downstream

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of Belgrade, where the Lower Danube starts. The 3.2 billion m^3 volume reservoir serves as an important sink for nutrients and hazardous and toxic pollutants from sources in the upstream Danube catchment.

The floodplain between the flood protection dike and the river bank contains cut-off oxbow lakes as well as flood channels and depressions, inlets, and remnants of wetlands and floodplain lakes. These different ecosystem types are ecologically important, and many are protected under the Ramsar Convention and the European Union (EU) Birds and Habitat Directives. A primary ecosystem service provided by the Lower Danube floodplain and Danube Delta is its capacity to support a rich biodiversity. The lower Danube area contains a number of endangered habitats and species (over 1,124 species of flora and 1,050 species of fauna in the lower Danube, and 1,642 species of flora and 3,767 species of fauna in the Danube Delta). Supporting ecosystem services include nutrient cycling and primary production, while provisioning services include fish, reeds, wood and drinking water, while regulatory services include flood protection, nutrient retention, groundwater recharge and climate regulation. Also dependent on the river and its basin in their daily lives are the 29 million people residing in the river basin who directly benefit from the many services provided by the river, including drinking water supply, flood protection, income production, and recreational pursuits.

About 75% of the original large floodplain area of the Lower Danube has been cut off from the river, and transformed into fish ponds or drained for agricultural use, reducing floodplain functions and typical habitats. A total area of 97,408 ha in the Danube Delta was cut-off from natural flow in 1990 (with about 39,974 ha dedicated to agriculture use). Because of the loss of the large floodplain areas, the remaining areas of river, fish ponds and floodplain lakes have become even more important refugia for flora and fauna. The floodplain has lost part of its ability to protect the surrounding watershed against floods and droughts.

The ongoing trend may lead to the loss of the remaining natural areas and the services they provide, as was demonstrated during the major floods in 2005 (displacing 2,000 people and inundating 690 km^2) and 2006 (displacing 17,000 people and inundating 1450 km^2). Navigation has been a major cause of environmental degradation on the Danube: activities that deepened, dammed or straightened the river have resulted in the destruction of parts of the remaining floodplains and wetlands, and significantly lowered the water table and threatened groundwater sources.

To address such concerns, the Convention for the Protection of the Danube River was agreed in 1994, and the Lower Danube Green Corridor Agreement, was signed by the governments of Bulgaria, Romania, Ukraine and Moldova in 2000, committing these governments to preserving a total of 935,000 ha, including enhanced protection for 775,000 ha of existing protected areas and new protection for another 160,000 ha; to restoring 223,000 ha of former wetland areas; and to promoting sustainable

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development along the Lower Danube. Further, the Lower Danube Green Corridor (LDGC), the most ambitious wetland protection and restoration project in the world, is intended to restore a floodplain area of 2,236 km^2 when fully implemented; moderate floods; restore biodiversity; improve water quality; and increase possibilities for better livelihoods. The restoration of the Lower Danube Green Corridor is enhancing biodiversity conservation, thereby also enhancing resilience to some climate change impacts. The UNDP/GEF Danube Regional Project ("Integrated Land Use Assessment and Inventory of Protected Areas") includes recommendations to rehabilitate floodplain areas and re-profile river channels; control soil erosion; improve hydrological conditions by removing underground drainage systems; and increase public awareness programs to promote restoration.

To address such concerns, the objectives of the LDGC are to: (i) increase capacity for long-term sustainable management by improving international cooperation for restoring, protecting, and sustainably managing the Lower Danube; (ii) reduce threats to freshwater ecosystems by mitigating and/or eliminating key threats from unsustainable agriculture, forestry and navigation; (iii) deliver successful field projects and communicate results from targeted field projects, highlighting socio-economic and ecological benefits of natural or semi-natural freshwater ecosystems; and (iv) ensure national policies for water management integrate experience from the field projects, encourage good practice in freshwater ecosystem management, and integrate the LDGC into major international processes. Floodplain restoration has reduced vulnerability to floods, while the diversification in livelihood strategies increased livestock grazing, seasonal pastures, and ecotourism.

Lessons learned

(1) In regions like the Lower Danube and Danube Delta, protection of individual high-quality reserves does not ensure provision of ecological functions over the long term;

(2) Using a sustainable ecological service approach for ecological restoration results in: (i) improved wetland functions, where the wetlands serve as hydrological and biogeochemical stabilizers, and provide ecological functions; (ii) improved socioeconomic functions; and (iii) benefits to the people and nature by ensuring sustainable livelihoods.

(3) Flood plain restoration in large-scale areas may also contribute to a more stable hydrologic condition by ensuring restored ecosystem services (including wetlands functioning) which, in turn, can result in more stable conditions for ecosystems and human beings, as well as increased resilience to climate change.

POLLUTION CONTROL

Hartbeespoort Dam (South Africa)

Source: Pollution Control: Application of Phosphorus Effluent Standards to Remediate Hypertrophic Hartbeespoort Dam (South Africa), contributed by Jeffrey Thornton and W.R. Harding, International Environmental Management Services Ltd, Waukesha, Wisconsin, USA

Hartbeespoort Dam is a multi-purpose water storage reservoir located in the North West Province of South Africa. It provides water resources ranging from bulk water supply to irrigated farming areas, to the supply of industrial process water and domestic drinking water in urban areas adjacent to and downstream of the impoundment. It also supports recreational uses, ranging from noncontact, passive recreational activities (picnicking, hiking along shoreline) to full-contact, active recreational activities (swimming, boating, waterskiing, etc.). Extensive urban development is present along the shoreline margins, with a portion of the impounded water utilized for domestic supply within the riparian community and in downstream urban centres. About 90% of the annual reservoir inflow is from the upstream Crocodile River.

Hartbeespoort Dam was for many years (1975-1985) the focus of one of the most comprehensive limnological investigations of a reservoir ever conducted. The study was a benchmark in developing an understanding of eutrophication, and resilience within highly regulated environments. Land use in its drainage basin is primarily

Major nutrient load reductions (on the order of 60% or greater) are required to bring about a sustained change in in-lake conditions in hypertrophic reservoirs like Hartbeespoort Dam.

rural agricultural, although the headwater portions of the Crocodile River system are the highly urbanized northern areas of the Johannesburg metroplex. The dam receives treated wastewaters from the Johannesburg-Krugersdorp-Pretoria conurbation. Excessive nutrient loads, originating largely as point source discharges from wastewater treatment works into the Jukskei River, have resulted in the reservoir being hypertrophic for many years. Large phosphorus loads (80-300 tonnes of phosphorus) discharged into the dam have supported sustained dominance of very dense aggregations of blue-green algae, producing a characteristic suite of user-related problems since the early-1970s, including: (i) tastes and odours in potable waters produced from the impoundment; (ii) the presence of blue-green algal toxins within the lake and treated waters derived therein; (iii) impaired recreational and aesthetic uses; and (iv) decreased revenue from lake-related commercial activities and residential sales.

To address these issues, Government Notice 1567 of 1980 prescribed a phosphorus standard of 1 mg/L as P for effluent discharges. Implementation of the standard was delayed until 1985, when it was decided to implement it only in the Vaal River to the Barrage, and in the Crocodile River Catchment to the confluence of the Crocodile with the Pienaars River, which contain five of the top ten impoundments identified as the highest priorities in terms of eutrophication. An informal receiving-water quality objective of 130 µg/L total phosphorus (TP) was introduced in 1988 for reservoirs in sensitive catchments, including Hartbeespoort Dam, which currently receives a median inflow concentration of about 700 µg/L as TP. Nine wastewater treatment plants currently discharge more than 8 million m^3 of treated effluent on a monthly basis into tributary streams draining to Hartbeespoort Dam (approximately 40% of the total water load to the reservoir). The average phosphate-phosphorus concentrations in the treated effluents ranged between 3 and 4.5 mg/L during 1986-1988, with the largest plants discharging effluents with concentrations between 4 and 5 mg/L phosphate-phosphorus. A few treatment plants have subsequently achieved the mandated 1 mg/L phosphate-phosphorus concentration, including the Johannesburg Northern Works which contributes between one-third and one-half of the total phosphate-phosphorus load to Hartbeespoort Dam.

Implementation of the standard coincided with the recovery of the reservoir, following the extensive drought conditions experienced between 1981-1982 and 1987-1988. Refilling the impoundment resulted in further dilution of the extremely high phosphorus levels observed in the waterbody, reducing in-lake phosphate-phosphorus concentration from nearly 0.5 mg/L to 0.13 mg/L. During that year, the blue-green alga, *Microcystis aeruginosa*, was virtually absent from the system for the first time in more than a decade. Concomitant and significant changes (increases) in zooplankton abundance, indicative of an increase in the grazing of herbivores, were also observed.

It was suggested in 1985 that simply setting an effluent concentration limit, rather than a limitation based on a total load, would have little beneficial impact. Given the phosphorus volume being discharged to the Crocodile catchment, it was further suggested that an effluent concentration limit down to 0.1 mg/L would probably still be inadequate. An assessment of the efficacy of the 1 mg/L standard subsequently proved inconclusive, due to lack of adherence to this standard within the drainage area. At the same time, residents reported improved water quality conditions, at least in the short term, with reduced occurrences of periods of heavy algal growths. These improvements were subsequently short-lived, with a return of extensive blue-green algae blooms during 2000, 2001 and 2003.

A public meeting was held by the Hartbeespoort Dam community to discuss the resurgence of algal blooms, one outcome being the formation of the Hartbeespoort Water Action Group (HWAG) charged with seeking short-term and longer-term solutions to the problem. HWAG realized a permanent solution would have to be found to address the causes of the algae problems, which remains a major, ongoing effort aimed at identifying and understanding the problems and their causes and implementing solutions. The interventions are centred on a three-pronged strategy, including (i) continuing to reduce the external phosphorus load to the reservoir; (ii) managing in-lake nutrient availability; and (iii) relaxing impaired food web structures that no longer support or provide a natural resilience to the eutrophication process. These longer-term efforts have been done in partnership with the appropriate governmental authorities at


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the national and provincial levels – namely, the Department of Agriculture, Conservation and the Environment (DACE) of the Government of North West Province (NWPG), and AGRICOR (Agricultural Development Corporation of Bophuthatswana), as well as the national water law.

Lessons learned

(1) Major nutrient load reductions (on the order of 60% or greater) are required to bring about a sustained change in in-lake conditions in hypertrophic reservoirs like Hartbeespoort Dam, being typical of highly regulated and nutrient-enriched environments such as reservoirs.

(2) While reduction of high external nutrient loading must remain a priority for long-term management of hypertrophic impoundments, benefits also may be derived from the manipulation of the food web (fishery), as a means of alleviating top-down control pressures that have become both established and resistant to change during the extended period such reservoirs have become eutrophic.

(3) There are indications that food web management may be an effective management intervention following nutrient load reduction control measures.

(4) Participatory approaches can produce valuable results in regard to identifying and addressing ecosystem degradation.

(5) Monitoring efforts, when appropriately undertaken, can provide useful information regarding ecosystem base-line conditions and for assessing degradation impacts.

ENVIRONMENTAL FLOWS

1. Rouse Hill Recycled Water Area (Australia)

Source: Sydney's Rouse Hill Recycled Water Area and its Discharge River System, Hawkesbury-Nepean River, contributed by Gunilla Björklund, Akkadia Consulting, Stockholm

The Hawkesbury-Nepean River system flows through the western edge of the Sydney basin of Australia, with a catchment area of 2.2 million ha. Its catchment includes World Heritage-listed wilderness areas, rainforests, open woodlands, heath lands, wetlands, and the Hawkesbury River estuary. The river system supports a diverse range of ecosystems, including the threatened Cumberland Plains Woodlands that provide a habitat for a large group of plants and animals. The system has nourished the Sydney Basin for thousands of years, more recently supporting agricultural and horticultural industries. The water that produces 70% of New South Wales goods and services comes from this system, which also provides the drinking water and sewage disposal system for more than five million people.

The Hawkesbury Nepean River sub-catchment is situated in the agricultural and peri-urban areas surrounding urbanized northwestern Sydney. Situated in this vulnerable region, the river is threatened by a multitude of land use impacts. Most natural vegetation in the catchment has been cleared for agriculture, housing and industry, with only 13% remaining intact. Chemical and nutrient runoff from industry, residential development and agriculture, and waste from more than 20 major sewerage plants, pollutes the river, causing frequent toxic blue-green algal blooms. Noxious weeds cover parts of the riverbanks and impede natural water flows, which also suffer from serious riverbank erosion. Polluted water from sewage treatment plants poses serious health risks to both humans and ecosystems. These impacts also are directly affecting the survival of native plants and animals dependent on the river system. The system's poor water quality is further exacerbated by the quantity of water constantly being drawn from it, resulting in decreasing water volumes where the degree of pollution has increased.

Ongoing actions to address such problems in the region are being implemented under the Hawkesbury Nepean Catchment Action Plan (CAP), some of which directly address degraded ecosystem functioning. The aim of the Greening Australia Hawkesbury-Nepean River Recovery Program is to rehabilitate 2,500 km of river, creek and stream banks by 2015 to ensure the future of the catchment's water quality, biodiversity and recreational values, including: (i) restoring and rehabilitating native riverbank vegetation; (ii) fencing to improve riverbank rehabilitation; (iii) removing

weeds and fostering re-establishment of aquatic native vegetation and their habitats; (iv) working strategically with stakeholders to address major causes of poor water quality (e.g., sewage treatment works); (v) working with government to ensure adequate water flows are maintained to protect the health of the river system; and (vi) improving the river system's resilience to climate change by early adoption of prevention and adaptation methods. Another activity is Sydney's Rouse Hill Recycled Water Area scheme, which helps decrease the environmental impacts of urban development on the Hawkesbury Nepean River. Sydney Water owns and manages the trunk drainage system in the Rouse Hill area. Under a framework of integrated water (cycle) management, it manages water, wastewater and stormwater together. Sustainable ecosystem management is achieved by activities in several areas: (i) monitoring the impacts of all three water sources on the quality of water in local rivers, including inclusion of a river management charge on water user bills; (ii) providing extra treatment of Rouse Hill water to a standard allowing it to be recycled and fed back to homes in the area in a separate pipeline for outdoor use and toilet flushing (non-recycled wastewater released into human-made wetlands, thereby providing ecosystem services while also reducing polluting substances, and imitating and speeding up the natural processes of the water cycle); and (iii) collecting Rouse Hill stormwater in grass-lined channels entering the stormwater system through a series of rubbish traps and wetlands, in order to reduce the pollutants entering the river system. Begun in 2001, the Rouse Hill scheme is estimated to have reduced demand for drinking water by about 40% on average, thereby also reducing Hawkesbury-Nepean River ecosystem degradation.

Since 1990, upgrading or closuring of sewage treatment plants, recycling water to decrease water discharges, providing sewerage services to previously-unsewered urban village areas, and providing improved sewerage services in the Blue Mountains and Western Sydney has resulted in remarkable improvements of Hawkesbury-Nepean River water quality. Work to date has contributed to a 75% reduction in the total phosphorus load discharged to the river, in spite of significant population growth within the catchment over the last 10 years. Streams in some areas are returning to a natural, near-pristine condition, with a marked increase in the number of some indicator species since the closure of the treatment plants. The Hawkesbury Nepean CAP, approved in March 2008, sets targets and timetables to: (i) improve riverine ecosystem conditions; (ii) improve the conditions and extent of important wetlands; (iii) reduce declining marine water and ecosystem conditions; (iv) improve the ability of groundwater systems to support groundwater-dependent ecosystems; and (v) improve estuarine conditions. The implementation timeframe for the Hawkesbury Nepean CAP is through 2016, and depends a great deal on stakeholder cooperation.

Lessons learned

(1) Any activity undertaken to address ecosystem impacts, whether it utilizes wetlands as a system for treating

storm water, or constructing fencing to improve riverbank rehabilitation, must be viewed as an integral part of sustainable use of river basin ecosystems, and the services they provide.

(2) Measures undertaken to ensure the provision of ecosystem services must be taken within an IWRM approach, within which urban impacts on water quantity and quality must be addressed together.

(3) Because every action undertaken in a given area can have impacts on downstream ecosystems and the services they provide, the sustainable development of a large watershed containing a large population requires an all-encompassing planning framework, particularly to ensure all the synergistic efforts of actions taken to ensure long-term sustainability are recognized.

(4) Rehabilitation can take a long time, and monitoring efforts are necessary to determine the extent rehabilitation goals are achieved.

2. Kelly Lakes (USA)

Source: Stream and Wetland Recreation at the Kelly Lakes (Wisconsin, USA), contributed by Jeffrey Thornton and T.M. Slawski, Southeastern Wisconsin Regional Planning Commission, Waukesha, Wisconsin USA

Upper and Lower Kelly Lakes are glacial lakes located in southeastern Wisconsin, in the southeastern portion of the City of New Berlin and western portion of the Village of Hales Corners. Lower Kelly Lake, a 1 ha spring-fed lake, drains northwards into Upper Kelly Lake. The 5 ha Upper Kelly Lake is located on a tributary to the Root River, which subsequently drains to Lake Michigan in the Laurentian Great Lakes. Upper Kelly Lake is elongate in shape with a single large drainage basin area of 398 ha, a mean and maximum depth of 5.2 and 9.4 m, and a volume of 260,000 m^3. Prior to 1950, the surrounding lands were primarily agricultural, resulting in the perennial stream that flows into Upper Kelly Lake being ditched, straightened and relocated to the west of Upper Kelly Lake. Current land uses within the drainage basin are primarily urban, with some open lands (wetlands, woodlands, other natural areas).

Residential lands are the principal urban feature of the Kelly Lakes drainage area, with about 3,370 persons residing in approximately 1,120 housing units within the Kelly Lakes drainage area in 2000. The Lakes, particularly Upper Kelly Lake, are visual and recreational amenities in this lake-oriented community, and also part of the City of New Berlin stormwater management system, providing both water quality benefit and flood management services.

By the late 1990s, the level of urban-density development in the watershed reached a level such that the lands surrounding the Kelly Lakes were identified as both a water quality and flooding risk in the City of New Berlin stormwater management plan. The inflowing Upper Kelly Lake tributary was channelized from the headwaters to its confluence with the lake, limiting the amount, quality, and diversity of available in-stream fisheries and macroinvertebrate habitat. The tributary and project site were characterized by unstable streambanks, sediment deposition from construction activities within the stream channel, habitat degradation from past channelization, wetland loss and degraded water quality as a result of urban nonpoint source pollution.

Historic channelization of the Upper Kelly Lake tributary led to a limited pool/riffle structure. While the streambanks were moderately stable, they were slightly entrenched with moderately steep banks. To meet flood management objectives, it was necessary to reconnect the stream channel with its floodplain, stabilize channel banks, and re-establish natural meanders and a more natural wetland plant community within the floodplain, thereby developing a stable, biologically diverse channel and a range of physically diverse habitats. Remedial measures included: (i) removal of between 0.5 and 1.0 m of historically placed fill from the project site; (ii) recreation of in-stream meanders; and (iii) establishment of native wetland vegetation adjacent to the stream and in its floodplain. Post-design analysis indicated the project decreased the 100-year flood stage by about 0.1 m within the newly-created floodplain/wetland, providing additional floodwater storage volume, and adequately preserving flood storage capacity. Further, because the stream was re-connected with its floodplain, sufficient floodwater storage volume was achieved to offset the placement of fill associated with a new pump house serving the City of New Berlin Water Utility.

Designing interventions mimicking the natural structure and function of aquatic systems can provide cost-effective, sustainable solutions to shared concerns, even in heavily-built urban environments.

Lessons learned

(1) Completion of this stream and wetland restoration project for Upper Kelly Lake and its inflowing stream highlights the success of an holistic approach to managing environmental problems.

(2) Stakeholder participation can be empowered by the process, leading to real, sustainable changes.

(3) Designing interventions mimicking the natural structure and function of aquatic systems can provide cost-effective, sustainable solutions to shared concerns, even in heavily-built urban environments.

(4) Coupling adaptive management and monitoring efforts provides a more efficient means for adjusting to changing ecosystem conditions.

ENHANCING STAKEHOLDER INVOLVEMENT

Lakes Osmansagar and Himayatsagar (India)

Source: Lakes Osmansagar and Himayatsagar: Two Drinking Water Reservoirs in Hyderabad, India, contributed by Mohan Kodarkar, Indian Association of Aquatic Biologists (IAAB), Hyderabad, India)

Lakes Osmansagar and Himayatsagar, twin drinking supply reservoirs, are located about 100 km northwest of Hyderabad. The Lakes were constructed in 1908 as a product of disaster management efforts following the devastating floods of the Musi River. The lakes have catchment areas of 740 and 1,307 km^2, surface areas of 22 and 21 km, and maximum depths of 31.7 and 23.9 m, respectively. The two reservoirs together supply more than 6,000 m^3 of drinking water, or about 5-10% of the total water demand of Hyderabad, the sixth largest city in India. A high level of biodiversity supported by these two ecosystems confirms their good ecological health (Osmangasar, for example, has 27 species of algae, 31 species of zooplankton and 17 species of fishes). The lakes support a flourishing fishery, and are used for recreational purposes and as picnic areas.

The watershed of the two reservoirs has undergone significant alteration over the past few years because of the development of large-scale rainwater harvesting structures. A recent study indicated that there is some kind of intervention, in the form of check dams, percolation tanks or contour trenching, for every 2 ha of the watershed. The structures have, in effect, blocked water flows on such a scale that the waterbodies have not reached Full Tank Level (FTL) in recent years, and have gone completely dry during some years. This situation is exacerbated by perceptible changes in the monsoon pattern over the last 25 years. Both reservoirs are exhibiting signs of eutrophication for want of sewage treatment facilities serving the urbanization littoral villages.

As an example, Chilkur, once a sleepy rural settlement on the shore of Osmansagar, has emerged as a major pilgrimage centre visited daily by thousands of people. Further, although the state government issued a number of provisions in 1996 for conserving these two drinking water resources – including prohibition of polluting industries, major hotels and residential colonies within a 10 km peripheral conservation zone, many violations of these provisions have resulted adjacent to the lakes and in their basins in recent years.

The real challenge to implementation of the comprehensive Government Order (GO 111) lies in determining how to meet the developmental demands and economic aspirations of the basin population, while at the same time maintaining the ecological integrity of the reservoirs. To this end, Hyderabad has a seen the emergence of a strong people's movement. The civil society demands can be articulated along the following lines: (i) obstructions to water inflows by check dams and other water harvesting structures must be removed to ensure natural water flows to maintain reservoir hydrology; (ii) organic farming must be promoted, and farmers provided with all possible incentives to reduce the load of pesticides and fertilizers on the water resources; (iii) funding must be provided to revive the forest reserves in the catchment areas of both reservoirs; (iv) commercial activities


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of a polluting nature must not be allowed in the reservoir basin; (v) a high-level committee with representatives from key government departments and civil society should review actual enforcement scenarios of GO 111 on a quarterly basis; (vi) decentralized and ecologically sustainable sewage treatment systems in basin habitations should be encouraged by a suitably designed subsidy policy to avoid surface and groundwater pollution; and (vii) modern technologies (e.g., global positioning systems and remote sensing) should be used to monitor the 22 water inlets feeding both reservoirs.

Lessons learned

(1) Water basins exert profound influences on the ecological health of their component ecosystems, in turn affecting ecosystem services, thereby requiring top priority in managing water resources.

(2) Synergy must be established between lake-basin and lake-dependent communities, typically requiring a single authority to coordinate inter-departmental activities, conflict resolution and the decision-making process, so as to maximize ecosystem benefits to all the communities.

(3) Alternate income generation opportunities for basin communities through the introduction of eco-friendly activities have the potential to prevent/preempt negative developments with adverse impacts on water resources.

(4) Laws enacted to protect water resources must be implemented in letter and spirit, including amending or developing laws to address challenges regarding the sustainable use of water resources.

(5) Handling the diverse impacts emerging from urbanization of reservoir basins is a major challenge for long-term sustainability, ecological integrity and uninterrupted flow of ecosystem goods from a water resource, including handling of sewage as a potential resource rather than as a waste management issue, and ensuring toxic industrial effluents receive effective treatment and safe disposal.

(6) Strong people's organizations, non-governmental organizations (NGOs), and knowledge and information-based networks have a special place in integrated ecosystem conservation and management, including functioning as watchdogs to facilitate good water and ecosystem governance.

INTEGRATED WATERSHED MANAGEMENT

1. Bermejo River (Bolivia, Argentina)

Source: Habitat Restoration: Stabilization of Erosion in the Binational Bermejo River Basin (Argentina, Bolivia), contributed by Jeffrey Thornton, International Environmental Management Services Ltd, Waukesha, Wisconsin USA

The transboundary Bermejo River Basin is an important tributary of the La Plata River located in southern Bolivia and northwestern Argentina. The river is 1,300 km in length, passing though the entire extent of the Chaco Plain, forming a link between the two major geographic features of the Andes Mountain Range and the Paraguay-Parana River system, and providing an important corridor connecting the biotic elements of the Andean mountains and the Chaco Plain.

This large river basin contains urban centers and areas of differing degrees of social, agricultural, commercial and industrial development, many producing goods of national significance, and all being sustained and supported at least partly, by the waters of the Bermejo River. The river exhibits an exceptional diversity of habitats, as well as great potential for human development and sustainable exploitation of its resources. Extensive livestock operations (cattle, sheep, goats) are widespread in the basin. Some crops (soybeans) are gaining importance in the piedmont zone of the upper basin in Argentina, and rice growing is increasing in the lower basin, with high seasonal demands on water resources.

Despite this wealth of natural resources, however, the basin population suffers from low income levels, and the education, health and sanitary conditions are among the

lowest anywhere in the two riparian countries. An estimated 1.2 million people were living below the poverty line in the late 1990s, with the indigenous population being the most disadvantaged, followed by rural workers and small-scale agricultural producers. Erosion and sedimentation are serious environmental problems in the basin, and severe soil erosion and desertification are found to varying degrees in much of the basin. As a result, soil productivity in the basin is low, resulting in unsustainable farming practices that exacerbate erosion and transportation of sediments into the river.

The initial step in the ecosystem stabilization and restoration process was preparation of a GEF-funded "Strategic Action Program for Binational Basin of the Rio Bermejo". The subsequently developed Strategic Action Program (SAP) is an instrument for coordinating the work of basin management between responsible local institutions, in order to achieve sustainable development of the basin by incorporating environmental concerns into development policies, plans and programs.

Preparation of the SAP was a joint effort by the governments of Argentina and Bolivia, working through the Binational Commission for Development of the Upper Basin of the Rio Bermejo and the Rio Grande de Tarija. As part of the SAP formulation, a number of interventions were undertaken to stabilize the highly-erodible sediments in the basin. These interventions, typically joint ventures between provincial governments, university extension services, and the local communities, included: (i) constructing check dams or soil erosion control structures in the upper portions of the basin; (ii) recreating terraces for sustainable agricultural development in the middle basin; (iii) restoring seasonal flooding of grasslands in the lower basin; and (iv) introducing community-based informational and educational programmes to encourage re-vegetation of river corridors in the lower basin and adoption of sustainable agricultural practices.

In addition, the proposed Multi-Use Project (APM) for the upper Rio Bermejo basin, sponsored by the governments of both countries calls for the regulation of flows in the Río Grande de Tarija and production of hydroelectric energy. These latter activities will allow regulation of water flows to increase minimum flows during the dry season, thereby facilitating the irrigation for large areas suitable for agriculture in Bolivia and Argentina, as well as generating hydroelectric power, providing partial flood control and supplying water for human and industrial consumption.

As a result of the SAP formulation, the Binational Commission for Development of the Upper Basin of the Rio Bermejo and the Rio Grande de Tarija has been strengthened by creating a framework for integrating the activities of the many organizations with responsibilities or involvement in managing water and other natural resources in the Bermejo River basin. The project also was successful in bringing about sustainable changes at the community level, including non-governmental organizations that helped shift the agricultural production base from pastoral activities to row crop cultivation. Removal of livestock reduced the impact of hooves on the soil surface, reducing erosion, while introducing row crops diversified the diet of the local population, contributing to enhanced public health.

Activities of the university extension service encouraged the introduction of terraced agriculture in the cloud forests of the Andean piedmont, reducing the degree of 'slash and burn' exploitation occurring on the cloud forest lands, while permitting more sustained use of the soils. In response to periodic inundation and flash floods, exacerbated by upstream deforestation, actions were introduced in the lower basin to include environmental education in the school curriculum, resulting in concerted community interest in sustainable activities (e.g., restoring riverine forests and protecting Bermejo River floodplains).

Lessons learned

(1) The practices installed in the basin will ultimately require maintenance or replacement, particularly in the case of check dams and other soil stabilization practices in the upper portions of the basin, necessitating a competent authority tasked with such management.

(2) Empowerment of local communities that embraced the structural interventions increased the probability that maintenance will be undertaken even in the absence of governmental interventions.

(3) A fully mature and functional basin management organization in the binational Bermejo River Basin will require further work, with many recommendations in the SAP yet to be fully implemented, due partly to basin-scale investments and interventions being beset by financial and political instabilities affecting the region.

(4) The success of community-level actions provides an excellent example of the adage, "think globally [at the basin level], but act locally."

SOUTHERN AFRICA

A. Southern African Development Community

Source: River Basin Management in Southern Africa: (A) River Basins in Southern Africa, contributed by Hillary Masundire, Department of Biological Science, University of Botswana)

Eleven countries share seven major river basins in southern Africa, including the Zambezi (8 states); Limpopo (4 states); Orange/Senqu (4 states); Okavango (3 states); Ruvuma (3 states); Cunene (2 states); and Komati (3 states). Some countries are riparians of several transboundary river basins, including Angola (4); Botswana (4); Mozambique (4); South Africa (4); and Zimbabwe (4).

The southern African river basins are associated with a wide variety of ecosystem services, including domestic and industrial water; agriculture; hydroelectric power generation; thermal power generation; wildlife reserves; navigation; tourism; fishing; mining; and timber and non-timber forest products.

Many southern African river basins are experiencing problems such as land degradation, water pollution, high water consumption and high water losses, all of which result in water scarcity and shortages (both quantity and quality). The Southern African Development Community (SADC) is attempting to address river basin management at the sub-continental (regional) level, but has encountered the following problems: (i) weak legal and regulatory framework; (ii) inadequate institutional capacities of national water authorities, regional and river basin organizations; (iii) weak policy framework for sustainable development of national water resources; (iv) poor information acquisition, management and dissemination systems; (v) low levels of awareness, education and training with respect to economic, social, environmental and political issues related to water resources development and management; (vi) lack of effective public participation by all stakeholders, particularly women and the poor; and (vii) inadequate infrastructure to meeting growing water service demands. To achieve regional

The importance of the SADC treaty and its protocols is to create an enabling environment for actions to be taken on the ground – in ecosystems – at the appropriate scale in space, time and institution.

cooperation, especially regarding ecosystem management, SADC states have signed several protocols under the SADC Treaty, including protocols on (i) shared watercourses; (ii) trade; (iii) education and training; (iv) mining; (v) development of tourism; (vi) wildlife conservation and law enforcement; (vii) fisheries; and (viii) forestry.

The SADC Protocol on Shared Watercourse Systems is most directly relevant to IWRM. Some of the principles guiding the protocol include utilization of shared watercourse systems within riparian states for agricultural, domestic, industrial and navigational uses, while maintaining a proper balance between resource development for a higher standard of living for their peoples and environmental conservation and enhancement to promote sustainable development. The latter include establishing close cooperation in regard to study and execution of all projects likely to have an effect on the flow regime of the system, and exchanging information and data regarding the hydrological, hydrogeological, water quality, meteorological and ecological conditions of such systems. It also includes establishment of river basin management institutions (e.g., river basin commissions, authorities or boards) with the responsibilities for developing monitoring policies for shared watershed courses, promoting the equitable utilization of shared watercourses, formulating strategies for developing shared watercourses, and monitoring execution of integrated water resource development plans for shared watercourses.

The importance of the SADC treaty and its protocols is to create an enabling environment for actions to be taken on the ground – in ecosystems – at the appropriate scale in space, time and institution. Further, the SADC Water Sector Coordinating Unit was established within the SADC Secretariat to facilitate implementation of the protocol, with some achievements being improved dialogue among SADC member states on issues pertaining to use and management of shared watercourse systems and establishment of three functioning basin management institutions, including the Okavango Joint Permanent Commission (OKACOM; 1994); Komati Basin Water Authority (KOBWA; 1992); and Orange-Senqu River Basin Commission (ORASECOM; 2000). Others are in the process of being created, including the Zambezi Basin Commission (ZAMCOM) and Limpopo Basin Commission (LIMCOM). Some results of these establishments include acceptance by SADC states of: (i) the requirement for Environmental Impact Assessments (EIAs) for developments that may have potential negative impacts on shared watercourses; (ii) the requirement for member states sharing a watercourse system to inform one another of any planned activity that may impact the ecosystem; and (iii) the establishment of an early-warning system in the Zambezi and Limpopo River Basins to monitor and inform downstream states of impending floods.

Lessons learned

(1) The SADC Treaty and its protocols provide a politically defined enabling environment for managing river basins as ecosystems.

(2) Establishment of river basin management institutions does not necessarily follow ratification of protocols; two of the three functioning basin institutions (OKACOM;

KOBWA) had already been established before the protocol came into force in 1998.

(3) Incentives for cooperation were more appealing than simply waiting for protocol ratification (e.g., South Africa and Swaziland went ahead with an agreement because of an urgent need to jointly manage the Komati River for the benefit of the two countries and avert looming conflicts relating to water use; ORASECOM establishment seems to have arisen because of acute water shortage in the basin).

(4) The urgency and acuteness of a shared problem tends to facilitate the development of agreements to co-manage shared ecosystems.

B. Okavango River Basin

Source: River Basin Management in Southern Africa: Okavango River Basin, contributed by Hillary Masundire, Department of Biological Science, University of Botswana)

The Okavango River Basin is located in Angola, Botswana and Namibia in southern Africa, covering an area of about 710,000 km^2. The basin, *sensu strictu*, covers an area of about 415,000 km^2, with slightly more than 600,000 people living within the basin which has no major urban centres. Much of the basin within Angola was ravaged by war for almost three decades resulting in very little development and, hence, little human-induced modification to the ecosystem. Although there are some human developments in Namibia and Botswana, the Okavango River is generally considered to be near-pristine. The Okavango River is among the few riverbasins in the world that empty into an inland delta, covering about 15,000 km^2. The hydrology of the Okavango is dominated by runoff from Angola.

The basin flora can be broadly grouped as aquatic and terrestrial, being used variously by the local communities for construction, energy, dug-out canoes, crafts, basketry, fish traps and for medicinal purposes. Fish are the dominant visible aquatic fauna, and are exploited for subsistence fishing, commercial fishing and recreational/sport fishing. There are three main groups of ecosystem beneficiaries in the Okavango Basin. The first is the local/native peoples who subsist on the natural resources of the basin. The second group of beneficiaries is commercial farmers who use the water of the Okavango for crop irrigation. The third group of beneficiaries is the tourists, especially in the Okavango Delta where tourism and hunting are significant contributors to the economy.

The three states sharing the basin have used the Okavango River Basin ecosystem to varying degrees and have aspirations for greater use of the ecosystem services. The governments of Angola, Botswana and Namibia decided that, in order to alleviate imminent, long-term threats to the linked land and water systems of the Okavango River, there is a need to: (i) manage the Okavango River basin as a single entity; (ii) jointly manage the basin's water resources and to protect its linked aquatic and terrestrial ecosystems and their biological diversity; (iii) promote coordinated and environmentally sustainable regional water resources development, while addressing the legitimate social and economic needs of each of the riparian states; and (iv) form the Okavango Joint Permanent Commission (OKACOM) to act as technical advisor to the governments of the three states on matters relating to the conservation, development and utilization of the resources of common interest to the states.

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OKACOM's responsibilities include: (i) determining the river's safe long-term yield; (ii) estimate reasonable consumer water demands; (iii) prepare criteria for conservation, equitable allocation and sustainable utilization of water resources; (iv) conduct investigations related to water infrastructure; (v) recommend pollution prevention measures; and (vi) develop measures for alleviating short-term water difficulties such as temporary droughts.

A GEF-funded transboundary diagnostic analysis (TDA) is nearing completion, and funding to develop strategic plans based on the TDA has been secured from the GEF. OKACOM also initiated the Environmental Protection and Sustainable Management of the Okavango River Basin Project (EPSMO) in 2003. Further, Botswana developed the Okavango Delta Management Plan (ODMP; also see next section) with the blessing of the OKACOM. Other results include information-sharing on river development (e.g., Namibia in regard to development of hydropower at Epupa) and to drought, as well as facilitating stakeholders to organize themselves to share experiences (e.g., "Every River has its People" stakeholder project)

Lessons learned

(1) Progress with the OKACOM accelerated after the SADC States ratified and began implementing the Protocol of Shared Watercourse Systems, with the SADC Treaty providing the overall politically-enabling environment for the basin states to engage in collaborative management work on the Okavango River Basin.

(2) Facilitated by OKACOM, a basin-wide stakeholder project ("Every River has its People") concluded that effective stakeholder participation in transboundary river basin management requires: (i) a shared vision with basin stakeholders participating actively with the OKACOM in basin co-management and development for enhanced livelihoods and sustainable development; (ii) appropriate Institutional mechanisms at local, regional, national and basin-wide levels; and (iii) development of a shared agenda based on agreed priority issues; this project clearly demonstrated the need and value of involving all stakeholders, utilizing the lowest possible governance level for implementation.

One achievement of the ODMP was to get sectors of government that normally do not communicate with each other to work toward the same goal.

C. Okavango Delta Management Plan (ODMP)

Source: River Basin Management in Southern Africa: Okavango Delta Management Plan (ODMP), contributed by Hillary Masundire, Department of Biological Science, University of Botswana)

The Okavango River forms an endorheic inland delta in the middle of the Kalahari Desert in northwestern Botawana. The delta area varies, being dictated by hydrology, including water inflows (through the river) and water losses (mainly due to evapotranspiration). There are perennial channels, pools and lagoons, seasonal channels, permanent and seasonal swamps all interspaced with high dry ground. The delta provides habitat for a wide and diverse range of flora and fauna. It also is home to about 150,000 inhabitants, most subsisting on fishing, crop production and livestock rearing. The abundance and diversity of wildlife makes the delta a tourist paradise. Tourism revenue generally exceeds US $4 million per year. Vegetation is used for construction (poles, reeds and grass), energy (firewood), crafts (carving and basketry), dug-out canoes and medicinal purposes.

Some delta uses are mutually conflicting (e.g., commercial fishing conflicts with subsistence and sport fishing; water abstractions conflict with maintenance of the wetland ecosystem). Other problems include land-use changes from increased urbanization, water quality impacts from waste disposal from tourist campsites, land degradation leading to soil erosion and siltation, and from uncontrolled and/or over-exploited natural resources,. There have been increasing conflicts between local communities and tour operators, because their activities often clash. Resurgence of tsetse flies in early 2000 led to spraying with chemical insecticides, raising concerns about impacts to the wider ecosystem. Other threats to the delta include developmental aspirations of the upstream states of Angola and Namibia. To curb potential conflicts between the various uses and users of the delta ecosystems, Botswana embarked on a project to develop the Okavango Delta Management Plan (ODMP), utilizing an ecosystem approach. The ODMP goals included: (i) developing a comprehensive, integrated management plan for the conservation and sustainable use of the Okavango Delta and surrounding areas, and (ii) integrating resource management for the Okavango Delta to ensure its long-term conservation and provide benefits for the present and future well being of the people, through sustainable use of its natural resources, with one of the key aspects of the plan being to engage as many stakeholders as possible. One achievement of the ODMP was to get sectors of government that normally do not communicate with each other to work toward the same goal, including regular meetings and discussions between government officers, local communities and the private sector. Several research projects are being conducted in the delta as part of ODMP implementation, including (i) the Darwin Initiative Project, which will enable simulation of aquatic biological diversity responses to future change scenarios involving basin climate and hydrology, which are crucial to informing policy decisions for biodiversity protection/conservation within the ODMP, and (ii) the BIOKAVANGO Project, created as a way to implement the ODMP biodiversity conservation component. A basin-wide study on environmental flows is currently underway under the auspices of both the OKACOM and the ODMP.

Lessons learned

(1) The ODMP project, aligned with the OKACOM from the beginning, could be used as a model for national planning in those parts of the Okavango River Basin in other OKACOM states.

(2) Although application of an ecosystem approach can produce products that all stakeholders can claim ownership of, the process can be physically, financially and emotionally exhausting.

(3) Although working at the grassroots level can achieve a great deal, there also is a need to have higher government levels in the process from the start.

(4) Effective ecosystem management will benefit from mainstreaming the ecosystem approach in all sectors involved in development planning and implementation.

(5) Applying the ecosystem approach enables sectors that do not normally work together can actively seek to set out and work toward achievement of common goals.

The Panama Canal has been described both as one of mankind's most spectacular engineering feats, and "the greatest liberty ever taken with nature."

(6) Ongoing work on environmental flows arose from discussions emanating from implementing both the Protocol on Shared Watercourse Systems and the OKACOM.

3. Panama Canal Watershed

Source: The Panama Canal Watershed: An Ecosystem-Based Management Approach, contributed by Marti Colley and Jorge Illueca, Environmental Consultants, Panama

Panama, the southernmost country in Central America, is a narrow land bridge connecting North America and South America. The Panama Canal Watershed (PCW) spans the narrowest part of the isthmus, extending over 5,527 km^2. The human-made Canal is the only waterway in the world draining into two oceans. Forests account for around half of the total land area, two-thirds being found in the seven protected areas covering 199,189 ha (36% of the total PCW; 10.4% of Panama's total protected areas). The Chagres National Park provides 80% of the water harnessed for human use. One of the world's richest biodiversity areas, the watershed provides a variety of habitats for numerous biological resources, particularly forests and macroscopic fauna. About 2.2 million people, almost two-thirds of the country's population, live immediately adjacent to the watershed in the cities of Panama and Colon and in-between areas, being directly dependent on the PCW for freshwater, hydroelectricity, flood control, etc. The level of socio-economic development within the watershed varies enormously. Most development has taken place in the east, close to Panama and Colon, and along the Transisthmic Highway connecting the two cities. This axis generates about 75% of Panama`s GDP and exports, and contains 50% of the total population. In contrast, the western region and the rural areas of the eastern region rank among the poorest in the country, with per capita incomes about a quarter of national levels, high poverty rates, little infrastructure, and fewer opportunities for inhabitants to improve their socio-economic situation. About 27% of land in the eastern region and 22.2% in the western region land are under cultivation, principally subsistence foods and small-scale crops, and livestock is raised on both a subsistence basis and as small commercial enterprises. The PCW's forests help regulate water flows, protect against soil degradation and sedimentation, act as a carbon sink, and serve as a habitat for numerous wildlife species that keeps the ecosystem functioning.

The freshwater flow in the PCW is used for drinking water, hydroelectricity, flood control, tourism and recreation, and operation of the Canal locks. It is also fundamental to the functioning of the surrounding ecosystem and sustains agriculture and farming for the poorer, rural populations directly dependent on the land for food production. Of the total freshwater extracted from the ecosystem, about 54.4% (2,553 million m^3) is used for navigation, 31.2% (1,465 million m^3) for hydroelectric generation, 9.5% (446 million m^3) as run-off surplus (i.e., flood control) and 4.9% (232 million m^3) for domestic and industrial use. Each ship transiting the Canal requires about 202,000 m^3 (52 million gallons) of freshwater, with a total daily requirement of about 8,080,000 m^3 of water for this purpose. The Panama Canal handles 5% of global shipping, with 13,147 ships transiting the canal in 2008. Its revenue from tolls and other services rose to a record US $2 billion for the year through September 2008, with almost US $699 million of this total transferred to the national economy.

The Panama Canal has been described both as one of mankind's most spectacular engineering feats, and "the greatest liberty ever taken with nature." The original construction cut the Americas in half, decapitated mountains, submerged 425 km^2 of pristine tropical forests under a human-made lake, displaced numerous human settlements that had been established for centuries, and caused vast expanses of wetlands to be drained, filled and sprayed with millions of gallons of crude oil to control mosquitoes. More recently, four development processes (intense population growth; uncontrolled urbanization; industrialization; deforestation) have put pressure on ecosystem resources, particularly freshwater supply and quality. Over the last half of the 20th century, the PCW population increased from 21,000 to 153,000 people, the number of people residing in nearby urban areas quadrupled from 400,000 to almost 1,600,000. In the process, one-third of the watershed's trees were lost to deforestation, largely by slash-and-burn agriculture, and only about half of the PCW remained under forest cover by 2001. Illegal

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deforestation activities have altered seasonal water flow patterns. Raw domestic, industrial and solid waste is flushed directly into rivers in the more populated areas, and certain secondary tributaries in the upper Chagras River watershed, because of inadequate water treatment facilities throughout the PCW. Many watercourses are severely polluted, with some becoming unsuitable for human use, even for recreational purposes. There is still no separation of sewage from rainwater drainage systems in many areas, and salinization is a growing concern. Management of Panama's natural resources also has been impaired by legal and institutional shortcomings of the agencies regulating it. Rapid environmental deterioration at certain points of the watershed is almost entirely due to slack environmental and zoning controls. Areas not under official protection are even more problematic.

The Panama Canal is undergoing expansion to allow the transit of substantially-large vessels and, when completed in 2014, will double the canal's tonnage capacity. The expansion involves building a third set of locks, widening existing navigational channels, deepening Lake Gatún by three feet, creating new freshwater reservoirs to service canal operations, and excavating and disposing of about 133 million m^3 of material. After fierce opposition from subsistence farmers in the western area, where new reservoirs were to be constructed, a solution involving constructing a set of water recycling basins to reduce the massive quantities of freshwater required by the new locks was found. This could allow seawater to flow into Lake Gatún, however, making it brackish with unpredictable consequences. Besides affecting drinking water, it could open a gate to salt water species that spawn in freshwater. Even if the water does not become contaminated, there are fears the canal expansion project will end up creating water shortages for the 80% of Panamanians living in the metropolitan area.

Activities to address such issues include: (1) institutional development; and (2) stakeholder involvement. Attempts to manage the watershed ecosystem as a whole only began after the handover of the Canal to Panama in 2000. The institutional structure for this purpose was established in 1997 with creation of the Panama Canal Authority (PAC) to: (i) administer, maintain, use, and conserve the PCW water resources; (ii) supply water to principal human settlements; and (iii) modernize the Canal. The PAC established the Inter-Institutional Watershed Commission (CICH) in December 2002 to administer, maintain, use, protect, develop and manage the watershed's natural resources, and promote its sustainable development, to ensure effective Canal operation and an efficient supply of potable water for neighbouring metropolitan areas, generation of hydroelectric energy, maintenance of biodiversity for future generations, and integration of resources and conservation efforts of several institutions to promote sustainable development and socio-economic growth. The government subsequently launched the Panama Canal Watershed Strategic Objective

Ecosystem management must be based on sustainable development principles that aim at alleviating poverty.

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Program (2000-2006), with the goal of achieving sustainable management of the PCW and its buffer areas. An Action Plan was prepared, with participation of local stakeholders, to address the principal socio-environmental problems identified by representatives of local communities. During the Plan`s first two years, an environmental awareness and educational activities programme was launched to generate support for sustainable management and development of the PCW. It was revised in 2003 to consolidate activities into two goals: (i) integrated watershed management, demonstrated in selected sub-watersheds; and (ii) upgraded environmental management of protected areas. Activities focused on domestic and industrial water quality and sanitation, waste management, water contamination from agricultural runoff, silvi-pastoral management, afforestation for soil stabilization and capacity-building for local committees to manage water resources. The programme was extended in 2007 into a third phase, focusing on consolidating improvements in protected areas management, furthering sustainable resource use in critical sub-watersheds and strengthening environmental governance.

The Plan produced several positive outcomes. Educational campaigns were successful in introducing environmental conservation and restoration, particularly of water resources, to people with little knowledge of such concepts. Communities were made aware that managing watersheds in a sustainable manner can increase individual income, or improve their quality of life in significant ways. They also experienced the benefits of participating with government and other institutions to find solutions to community problems.

Both governmental and non-government organizations also gained experience in implementing cross-sectoral watershed management projects addressing specific environmental problems. Local government institutions and organizations also were made more aware of norms for best practices in clean agro-production. Livestock raisers were made aware of laws for clean disposal of livestock wastes, and understood why it should be prevented from contaminating the watershed. Unsustainable traditional agricultural practices, including slash-and-burn cultivation of fields to remove weeds and unwanted bush, were actively discouraged and preventive measures introduced. Agrochemical overuse, and growing on slopes with low productivity soils, were discouraged and farmers given more technical input from agricultural organizations. Community and institutional involvement was promoted to establish tree nurseries for reforesting with native species to protect freshwater resources (streams, rivers, springs, wells, etc.) and to restore the soil and decrease erosion and siltation. Water supply and sewage disposal infrastructure also was improved or installed in many rural communities and schools to allow adequate access to fresh water resources in neglected communities.

Lessons learned

(1) An appropriate governance structure for effective coordination and cooperation is essential to achieve sustainable integrated watershed management, and cooperation is fundamental to creating synergies and avoiding undesired duplication of efforts.

(2) Political will to establish governance over freshwater resources is essential, with projects given governmental priority being in a much better position to succeed.

(3) Sustainable ecosystem management plans can only succeed if implemented, and environmental laws can only have an impact if enforced.

(4) Institutional behavioural change is generally a slow process achieved only with time and persistent effort.

(5) A solid diagnostic study of the status of a watershed, based on reliable scientific and technical information and data, is critically important for designing a solid, ecologically sound integrated watershed management plan and strategy.

(6) Protection of existing, intact, vegetative watershed cover remains the best, lowest-cost option for any watershed management program.

(7) Actions with direct financial or material benefits to key players will be most likely to succeed.

(8) Best practice is to implement ecosystem management plans at the sub-watershed level and build on small successes.

(9) It is necessary to monitor and evaluate the effects of an ecosystem management plan, using a clear set of environmental indicators designed to determine whether actions are achieving their goals.

(10) Ecosystem management must be based on sustainable development principles that aim at alleviating poverty.

4. Bang Pakong River (Thailand)

Source: Bang Pakong: Addressing Ecosystem Services via the IWRM Approach, contributed by Mogens Dyhr-Nielsen, DHI, Denmark

The rich natural resources and biodiversity of the Bang Pakong River Basin in Thailand has supported the livelihoods of many communities for centuries. The basin has a total drainage area of about 18,500 km^2 and can be divided into the upper Prachinburi River Basin and the lower Bang Pakong River Basin. Because of its proximity to Bangkok, the basin has experienced rapid industrial and agriculture development and rapidly-increasing water demands. Water allocations have had significant impacts on ecosystem

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services provided by the rivers, leading to issues affecting the resources and livelihoods of the people. Below the hilly ranges in the catchments in the upper parts of the Prachinburi River, the basin`s flat topography is ideal for rice and other farming activities. The basin's natural water storage capacity is limited, but there are several dam sites for storing water for dry season water demands.

The lower part of Bang Pakong is a tidal river, with a brackish water ecosystem reaching 120 km upstream during the dry season. This important estuary ecosystem is characterized by high biological productivity, and supports a highly-profitable shrimp industry and coastal tourism industry. Diverse estuarine plant communities, especially mangrove forests, provide an important habitat, feeding grounds and nursery area for many fish species. The population of the drainage area of Bang Pakong and Prachinburi River basins is nearly two million, with one-third living in the province of Chachoengsao. The basin population is mostly rural, with rural poverty being a major downstream concern.

The Bang Pakong Basin provides a number of ecosystem services, including source water for irrigation, urban and industrial water supply. Agriculture has for centuries been the most important activity in the basin, providing livelihoods and alleviating poverty. More than 70% of the total land area is dedicated to agriculture, with 95% of the basin's available water being used for irrigated agriculture. Shrimp farming has become an increasingly important activity in recent years, extending into Thailand`s central plain freshwater areas, previously under paddy cultivation. Seasonal availability of brackish water within streams and irrigation canals also has encouraged intensive shrimp farming along the river more than 100 km from the coast. Urban and industrial development within the basin has increased in recent years, with industry now competing with the irrigation sector for water. New industrial zones host polluting industries, with many factories discharging minimally treated wastewater. Following rapid population growth, combined with economic development, the Bang Pakong Basin water resources are now heavily exploited by the agriculture, industry and urban sectors. Further downstream, the estuarine lower reach of the Bang Pakong is perfect for the river shrimp, Gung Yai, one of Thailand's major delicacies, as well as home to endangered species (e.g., Irawaddy dolphin). It also has important recreational potential. Characterized by high biological productivity and diverse estuarine plant communities (especially mangrove forests), the estuary is an important habitat, feeding ground and nursery area for a variety of fish species, as well as offering opportunities for increased waste assimilation and bank erosion control.

The Bang Pakong ecosystems have become increasingly threatened by water allocations and demands from agricultural, industrial, and household users over the last 20 years, and water pollution impacts. Farmers along the river now run out of freshwater in the dry season, and freshwater shortages have become serious in the Bang Pakong area, since upstream industries utilize the water and transfer it to nearby Chonburi province. Many local people find construction of three reservoirs, instituted to manage water resources issues, a major cause of many problems, including more than 100 land erosion hotspots along the river bank. Water quality issues in the estuary from shrimp farming are compounded by domestic and industrial wastewater discharges and agricultural point sources. Complex water uses by modern agricultural and marine activities and certain water management structures have exacerbated the pollution problems. The river is now so polluted that economic livelihoods have been drastically altered. A major water resources facility within the basin is the Bang Pakong Diversion dam, located about 70 km from the rivermouth, and constructed to divert and store 30 million m^3 of freshwater for different uses, mainly urban, and to prevent saltwater intrusion into irrigation areas during the dry season. The natural estuarine flows have been disrupted by closing of the dam gates, and the water quality along the river's banks has deteriorated. The land below the dam structure was flooded by seawater tides, whose upstream movement was barred by the dam, and the river's banks are being eroded by tidal waves amplified by the 900 m dam wall.

Addressing such problems requires managing the basin's resources in a more holistic manner, considering not only water allocation issues, but also the benefits of all ecosystem services. To this end, the Royal Irrigation Department (RID) established a Master Plan for Water Resources Development

Experience over the last ten years has demonstrated the importance of coherent management of ecosystem services to maintain human welfare, as well as social and political stability.

and Management in Eastern Region in 2000, emphasizing water allocation to address rapidly-increasing water demands, as well as pending water conflicts. The main water-related problems in the basin were water shortages, water quality and flooding. The plan identified reservoir construction as the primary solution to upcoming water shortages. The issue of ecosystem health, however, was ignored, despite its fundamental importance to economic livelihoods.

An IWRM plan was developed for the river basin in 2004 with stakeholder participation, specifying strategies to mitigate and prevent water pollution by reducing pollutants from domestic, agriculture, aquaculture, and industrial wastewater. The focus was again on water quality (including salinity), rather than ecosystem health. One result was that the RID was quickly compelled to cease operations and evaluate options for future operation of the dam, and an environmental impact assessment was initiated. Although studies were made to find more appropriate operation rules to minimize detrimental dam operation effects, the dam continues to be kept fully open, however, as a political compromise. Further, traditional rice growing and small fishery are being slowly replaced by private agricultural enterprises. Over the past ten years, many farmers and fishermen have turned to pig, shrimp and fish farming for additional income.

Over the same period, national authorities recognized that efficient water resources management requires strong local management and, hence, the need for decentralization. The National Water Resources Council established the Bang Pakong River Basin Committee (BPRBC) in 2001, with the mandate of managing water resources regulation of the basin. The BPRBC consists of representatives from relevant governmental agencies, local governments, and from every stakeholder group, with a mandate of managing basin water resources. The Bang Pakong Dialogue Initiative was established to help the involved parties find solutions to the river's problems, while at the same time strengthening the work of IWRM in the basin and the capacity of the River Basin Committee to fulfil its mandate to reduce conflicts within the river basin. A public awareness campaign was also launched, targeting about two million people living in the basin. Although the Dialogue Initiative has served locals

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in dealing with conflicts in specific local areas, concerns still exist regarding ecological damage from interventions beyond the local scale.

Experience over the last ten years has demonstrated the importance of coherent management of ecosystem services to maintain human welfare, as well as social and political stability. It is also apparent that the Thai Government, local communities and the private sector have been paying much attention to addressing the problems, with this case appearing several times in various international contexts. Nevertheless, little appears to have changed for the better in the river ecosystems over the period. The barrage remains decommissioned to avoid even worse situations, and the reservoir releases still appear insufficient to maintain the

Much trouble and wasteful spending may have been avoided if the traditional water allocation and pollution approach of the 1980s had been replaced by an ecosystem approach.

environmental flows in the dry season. It also will take a long-term effort to reduce nonpoint source pollution loads, as well as the more controllable municipal and industrial wastewater point sources, and to balance available water resources against water demands in one of Southeast Asia's economic hotspots. Local communities are so attached to their local ecosystems that they can be politically mobilized to force the closure of major government-constructed water infrastructure. Still, there are no readily available solutions for ecosystem problems, and a persistent, decade-long effort is required. One result of these efforts appears evident. Much trouble and wasteful spending may have been avoided if the traditional water allocation and pollution approach of the 1980s had been replaced by an ecosystem approach. It also appears the formal introduction of IWRM during the 1990s was not sufficient to provide the needed results. Thus, there is a need to move forward to find approaches where one takes points of departure in managing "the benefits of water" and not just "the water".

Lessons learned

(1) The conventional IWRM focus on water allocation and pollution, with limited attention paid to fisheries and freshwater-coastal water interfaces, was insufficient to account for all the various local interests or benefits in the basin, and caused decommissioning of a costly barrage infrastructure because of public and political pressures.

(2) Communities depend on the benefits of ecosystems, more than on the water itself; and truly integrated water resources management must focus on the "benefits to people," not just on "water" *per se*.

(3) Local community wisdom and knowledge counts as much as academic studies; local people often know about their local ecosystems and their multiple benefits through age-old experiences and observations carried out through generations, and can provide important and useful insights which may never be achieved with traditional scientific approaches.

(4) Integrated water management is about local people and politicians as much as it is about water experts and bureaucracies.

(5) Because remediating failures in managing ecosystem benefits takes time, it is important to address the issues early in the planning phases.

CHAPTER FOUR

Response options on water security for sustainable ecosystem services

Because of their fundamental role in supplying life-supporting services critical to human existence and well-being, ecosystems have been described by some as “engines of production,” and as “natural infrastructure and foodstores”. And based on the case studies and experiences summarized in the previous chapter, it is clear that water security and properly-functioning ecosystems also represent a critical connection.

The Millennium Ecosystem Assessment, however, highlighted a continuing trend of ecosystem degradation throughout the world, with obvious consequences on the ability of ecosystems to deliver services (MA, 2005a, 2005b). Water systems (rivers, lakes, groundwater) are the most sensitive to such degradation, being accurate indicators of degrading human activities in the surrounding watersheds.

Against this background, water security represents a unifying element supplying humanity with drinking water, hygiene and sanitation, food and fish, industrial resources, energy, transportation and natural amenities, all dependent upon maintaining ecosystem health and productivity. Positive evidence of the benefits of economic development inherent in sustainable ecosystem services – and the water security required to provide them – makes it appropriate to take action to develop and disseminate these concepts. In view of increasing population numbers and associated resource demands, natural resources managers must also increasingly consider how to best balance ecosystem services among sometimes competing users, in order to achieve the maximum benefit for the largest number of people without compromising sustainable ecosystem functioning. This means that IWRM, as a more holistic approach to managing water systems, also must balance ecosystem services to be most effective, including the goal of enhancing ecosystem resilience.

The 3rd World Water Development Report identifies a range of response options existing both within and outside the water domain for addressing water resources issues. One option is to support institutional reforms to allow them to better deal with current and future water challenges, including such actions and programmes as decentralization, stakeholder participation and transparency, increased corporatization where feasible and fair, and partnerships and coordination involving public-private, public-public, and public-civil society linkages. Another option is due consideration of formal and informal water law influences on water resources, including relevant regulations in other sectors that coincidentally influence water resources management either directly or indirectly. Consultation with stakeholders as a means of ensuring accountability in water resources planning, implementation and management is an important option, as well as a means of building trust. Also needed is the development of institutional and human capacity for sectors both inside and outside of the water domain, ranging from traditional forms of education to on-the-job training, e-learning, public awareness raising, knowledge management and professional networks.

Because the range of response options noted above also underlie broader actions and programmes, governments must take specific actions to ensure sustainable ecosystem services and water security. The various organizations comprising the United Nations and its specialized agencies also can act in many ways to facilitate this goal. The Water Policy and Strategy of the United Nations Environment Programme (UNEP), and its focus on ecosystem-based management approaches to water resources, provides a useful guide for this purpose. As discussed further below, actions and programs directed to optimizing, balancing and sustaining water-related ecosystem services are at the core of this goal.

Consider ecosystem services and water security early in economic development activities

Economic development as a means of improving human health and economic livelihoods, as exemplified in the targets of the Millennium Development Goals, is a pursuit of governments around the world. And past experience suggests that some level of economic development appears to be a prerequisite for enabling environmental and ecosystem concern. The very poor, for example, are both causes and victims of environmental degradation. They must do what is necessary to survive, without always being able to consider the negative environmental consequences. In contrast, the developed countries use a disproportionately large quantity of the Earth's resources because of their relative wealth, and their consumption and production patterns. As a result, consideration of the ecosystem consequences of such activities often may be ignored, or only considered in later stages of national economic development plans and programmes.

Thus, a recommended action is to ***recognize and optimize ecosystem services during – rather than after – development and implementation of national economic and related water-resources plan and policies.*** This recommendation includes ensuring that ecosystem resiliency is considered in planning activities, as well as in adaptations to climate change, at whatever scale they are undertaken.

IWRM must balance ecosystems services to be most effective.

Human demands for ecosystem services continue to increase with increasing population growth, agricultural development and industrialization. Because ecosystems typically provide multiple services, and because different sectors will have differing ecosystem service needs, water resources managers will increasingly be faced with the problem of balancing ecosystem services, particularly as a means of resolving resource use conflicts. This need also is apparently Thus, ***IWRM efforts must recognize the need to manage and balance the benefits to be derived from water resources, rather than simply managing the water resource itself.*** These benefits include the whole range of provisioning, regulating, and cultural services (water supply, food, fuelwood, water purification, flood control, recreation, etc.)

This perspective represents a departure from the traditional water allocation and pollution control approach that characterized the 1980s, and facilitated the emergence of an

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ecosystem approach to complement the traditional focus of IWRM efforts.

Undertake activities directed to enhancing ecosystem services via water security

The previous chapter provided examples of many approaches to enhancing, restoring or maintaining ecosystem services. Although many were not explicitly implemented as an integral component of a comprehensive IWRM approach, they do provide examples of actions and programmes undertaken to enhance both ecosystem services and water security. These useful examples ranged from habitat restoration to pollution control to watershed management. They were meant to illustrate the importance of identifying and enhancing ecosystem provisioning, regulating, cultural and supporting services in a range of environmental and socioeconomic settings. Further, although not necessarily integral parts of economic development plans and activities, their value in ensuring ecosystem services and water security is evident.

Another recommended action is to ***develop and implement activities directed to enhancing the functioning of ecosystems, and enhancing water security at all scales (regional, basin, national, local)***. As identified in Chapter 2, and discussed in many of the case study summaries provided in Chapter 3, there are a range of specific activities relevant to this goal, including habitat restoration, ecohydrology, pollution control, maintenance of environmental flows, and watershed management.

Rehabilitate degraded ecosystems

This report has emphasized the need to maintain or rehabilitate ecosystems in order to ensure sustainable ecosystem services, including the fundamental role of water security in facilitating ecosystem sustainability. Degradation and over-exploitation reduces the range of potential ecosystem services, with consequences for human health and well-being, as well as the sustainability of the ecosystems themselves. Multiple examples of the value of rehabilitating ecosystems, using a variety of approaches, were provided in the previous chapter, highlighting the utility of this approach. Thus, it is recommended that ***governments and other ecosystem service stakeholders should mobilize resources to identify, evaluate and rehabilitate degraded ecosystems***.

Undertake appropriate ecosystem monitoring activities

Environmental conditions are a function of both natural and human-induced drivers and influences. Economic development activities also are not static processes. Inadequate data also was cited as a deficiency in the Millennium Ecosystem Assessment (MA, 2005a, 2005b). Ecosystem management activities, therefore, must be accompanied by a means of monitoring progress. Accordingly, ***ecosystem rehabilitation activities should be accompanied by monitoring activities, both during and after their implementation***. Monitoring serves multiple purposes, including determining baseline conditions, identifying trends and assessing progress made in addressing ecosystem degradation and, in some instances, enlightening hard-to-see connections (ILEC, 2005). Monitoring information and data also serves as a basis for making adjustment to management programs over time.

Adaptive management to accommodate changing management goals

Ecosystem changes are inevitable as the human population continues to grow, with accompanying increasing demands for natural resources, including freshwater. The availability of ecosystem services, therefore, also will change over time. Economic development activities, in turn, will be affected by ecosystem changes. Although sustainability remains the overall goal, it also must be recognized that ecosystem and economic development changes, as well as unanticipated emerging issues, must be acknowledged and accommodated in the pursuit of this goal. Thus, it is recommended that we ***maintain consistency, but also allow for adaptive management to accommodate needed adjustments*** to changed ecosystem and water security management goals. Data and information gained

The concept of ecosystems as providers of provisioning, regulating, cultural and supporting services to humanity is becoming more widely acknowledged among the scientific community and, to some degree, within the economic sector.

from monitoring activities will significant aid in such adaptive management considerations.

Develop partnerships to promote management of balanced ecosystem services

Fostering and promoting balanced ecosystem services and water security can be pursued at many scales, and within the context of both ongoing and planned programmes. Such activities can obviously be enhanced by collaboration and cooperation. This goal requires the development of appropriate partnerships to provide synergy regarding sustainable ecosystem functioning. It also will facilitate development of common visions regarding the roles, functions and sensitivity of water systems to human activities.

Such collaborative partnerships can be developed at many levels, including governmental, non-governmental organizations, social and religious organizations, and within the context of civil society. Accordingly, another recommended action is to ***engage partnerships to promote management of balanced ecosystem services and water security.*** In addition to unilateral and multilateral governmental programs and activities, there are a range of potential partners for pursuing this goal, including UN-Water, IUCN, Global Water Partnership, World Wide Fund for Nature, The Nature Conservancy, and the Global Environment Facility, to cite a few prominent examples.

Utilize global venues to promote management of balanced ecosystem services

There are a multitude of global-scale water-related conferences, meetings, workshops and symposia that take place because of significant interest in specific topics, or as periodic, recurring events. These include professional society meetings, as well as gatherings on a broader or larger scale. Although focusing on specific issues, the concept of maintaining or rehabilitating ecosystem services underlies many of these gatherings. Previous major international gathering, including the 1972 Conference on the Environment, the 1992 International Conference on Water and the Environment and the Conference on Environment and Development (Earth Summit), and the 2002 World Summit on Sustainable Development, are examples of global-scale discussions on various elements of both sustainable ecosystem services and water security, whether or not explicitly recognized as such. Even gatherings not explicitly directed to ecosystem services and water security often touch upon these issues in their discussions and goals. Examples of the latter include the FAO's 1995 World Food Summit and the UNCHS 1996 Sustainable Cities Summit. Such venues will continue to be major fora for discussion of water systems and the ecosystem services they provide.

Another recommended action, therefore, is to ***promote coherent organized management of balanced ecosystem services through relevant global-scale venues***. Prominent examples include the World Water Forum, the Commission on Sustainable Development, World Water Day and the Stockholm World Water Week.

Establish coherent ecosystem services goals and activities within the UN organizations

As a follow-up process of the 2002 World Summit on Sustainable Development, UN-Water was endorsed by the United Nations to support States in their water-related efforts to achieve the Millennium Development Goals. UN-Water is comprised of 24 UN agencies, programs and funds involved in water polices to varying degrees, including UNEP, UNESCO, UNDP, UNESCO, WHO, FAO, WMO, World Bank, and various non-governmental organizations, among others. It represents the inter-agency mechanism that promotes coherence in, and coordination of, UN system actions directed to implementation the Millennium Development Goals, with the overall goal of improving cooperation between these governing bodies and development organizations.

Ecosystem services and water security underlie the activities of many of these agencies and organizations. Accordingly, it is recommended that ***optimizing ecosystem services become a core goal in the activities and programmes***

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developed and implemented by member organizations of UN-Water. In addition to serving as a basis for cooperation, this goal represents a unifying element in the development and implementation of the activities of this diverse group of UN organizations.

Increase public awareness about ecosystem services and water security

As stated early in this report, the concept of ecosystems as providers of provisioning, regulating, cultural and supporting services to humanity is becoming more widely acknowledged among the scientific community and, to some degree, within the economic sector. Nevertheless, the traditional view of treating water resources as a commodity like minerals or oil remains a reality on many levels. The fundamental linkage between ecosystem sustainability and water security also remains a vague concept to many. Further, the Millennium Ecosystem Assessment (MA 2005a, 2005b) indicated that ecosystem degradation and over-exploitation continue in many regions of the world. It is clear, therefore, that knowledge about the fundamental role of ecosystem services in supporting human health and well-being, and the intrinsic linkage between sustainable ecosystems and water security, must be better expressed and disseminated. To this end, another recommended action is to ***create more general awareness about ecosystem services, and the linkages between these services and water security, among governments, decision-makers, the general public, industry and the media***. This is one of the goals of this report, and the professional and global venues identified above are prominent outlets for dissemination of such information and data. Widespread acceptance of the importance of ecosystem services, and their linkages to water security, requires widespread knowledge of these elements. Creating public awareness, therefore, remains a major and formidable goal.

In closing, it is reiterated that the purpose of this report, despite its brevity, is to serve – as Achim Steiner notes – as food for thought, and facilitate discussion, about the linkages and interactions between human survival and well-being, and the ecosystem services and water security necessary to address these needs. The targets identified in the Millennium Development Goals also depend fundamentally on these linkages and interactions. Accordingly, water security and ecosystem services must be given the same degree of importance in national development programmes as social welfare and economic growth. All are basic components of sustainable development. Further, this ecosystem-based water resources management approach should be implemented as rapidly as possible, since it can take decades before we master the political, institutional and technical aspects that enable humanity to utilize the full potential of ecosystem services and water security.

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Coordinated by the World Water Assessment Programme, the *United Nations World Water Development Report 3: Water in a Changing World* (WWDR3) is a joint effort of the 26 United Nations agencies and entities that make up UN-Water, working in partnership with governments, international organizations, non-governmental organizations and other stakeholders

The United Nations' flagship report on water, the World Water Development Report offers a comprehensive review of the state of the world's freshwater resources and provides decision-makers with the tools to implement sustainable use of our water. The WWDR represents a mechanism for monitoring changes in the resource and its management and tracking progress towards achieving international development targets. Published every three years since 2003, it offers best practices as well as in-depth theoretical analyses to help stimulate ideas and actions for better stewardship in the water sector.

The current report, *Water security and ecosystem services: The critical connection* has been prepared by the UNEP as a contribution to the World Water Assessment Programme and offered to the partners of UN-Water for their consideration.

This is part of the Dialogue series of side publications accompany the WWDR3, providing more focused, in-depth information and scientific background knowledge, and a closer look at some less conventional water sectors. These series provides scientific information on subjects covered in the WWDR and serves as bridge between the WWDR3's contents and scientific, peer-reviewed publications.

World Water Assessment Programme side publications, March 2009

During the consultation process for the third edition of the World Water Development Report, a general consensus emerged as to the need to make the forthcoming report more concise, while highlighting major future challenges associated with water availability in terms of quantity and quality.

This series of side publications has been developed to ensure that all issues and debates that might not benefit from sufficient coverage within the report would find space for publication.

The 17 side publications, including this one released on the occasion of the World Water Forum in Istanbul in March 2009, in conjunction with the WWDR3, represent the first of what will become an ongoing series of scientific papers, insight reports and dialogue papers that will continue to provide more in-depth or focused information on water–related topics and issues.

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