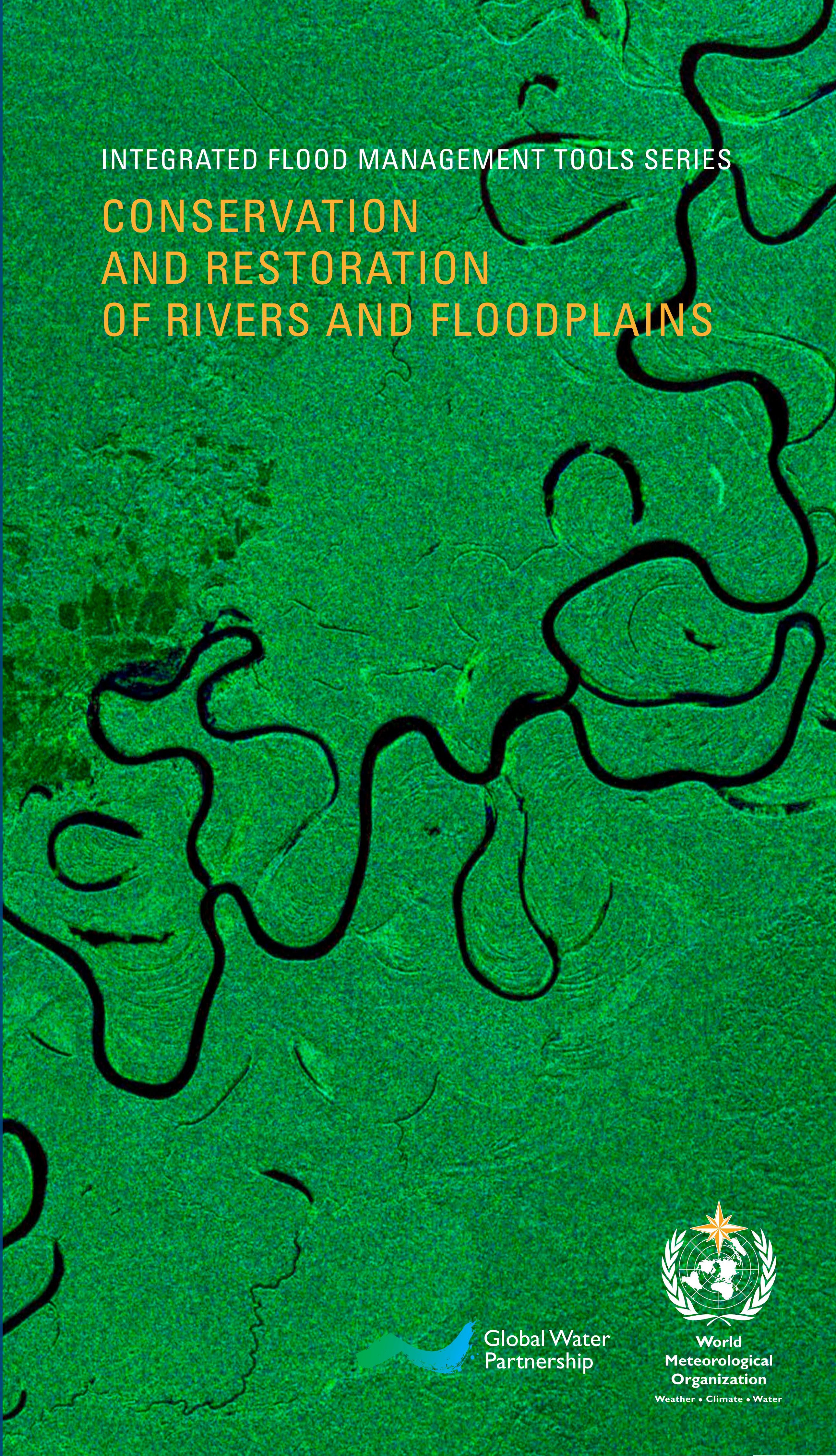

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CONSERVATION AND RESTORATION OF RIVERS AND FLOODPLAINS

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To the reader

This publication is part of the *"Flood Management Tools Series"* being compiled by the Associated Programme on Flood Management. The *"Conservation and Restoration of Rivers and Floodplains"* Tool is based on available literature, and draws findings from relevant works wherever possible.

This Tool addresses the needs of practitioners and allows them to easily access relevant guidance materials. The Tool is considered as a resource guide/material for practitioners and not an academic paper. References used are mostly available on the Internet and hyperlinks are provided in the *References* section.

This Tool is a *"living document"* and will be updated based on sharing of experiences with its readers. The Associated Programme on Flood Management encourages disaster managers and related experts engaged in river and floodplain restoration around the globe to participate in the enrichment of the Tool. For this purpose, **comments and other inputs are cordially invited**. Authorship and contributions would be appropriately acknowledged. Please kindly submit your inputs to the following email address: apfm@wmo.int under Subject: *"Conservation and Restoration of Rivers and Floodplains"*.

Acknowledgements

This Tool makes use of the works of many organizations and experts, as listed in the references. Acknowledgement is due to Mr Robert McInnes for his competent expertise and for bringing various perspectives into focus under technical guidance of the APFM Technical Support Unit.

EXECUTIVE SUMMARY

CONSERVATION AND RESTORATION OF RIVERS AND FLOODPLAINS: SERVING MULTIPLE OBJECTIVES IN MANAGING FLOODS

1 The loss of wetlands is more rapid than for any other ecosystem (Millennium Ecosystem Assessment, 2005a). Rivers and floodplains have not been immune to this loss and continue to be degraded. Whilst significant efforts have been made across the globe in recent years to restore many impoverished river systems, often opportunities to truly optimise benefits across a range of stakeholders have been missed. Often this is not a planned or nefarious action, it is simply driven by basic ignorance borne out of poor cross-sectoral planning and a lack of awareness of the possibilities.

2 Against this backdrop of wetland loss and progressive damage to river and floodplain ecosystems, research suggests that the frequency of great floods has increased substantially during the twentieth century. Climatic models also suggest that this trend will continue into the future (Milly et al., 2002). The increasing frequency of flood events has generated a commensurate increase in total damage, which partly explained by climatic factors also, possesses a strong societal element. Increased flood damage is associated with not just increased precipitation but also with increasing population size and density and increased wealth and infrastructure residing within floodplains.

3 As flood damage has increased, the biodiversity which supports the ecosystem services from which society benefits has suffered significant losses. Whilst the biodiversity has an intrinsic or existence value in its own right, the multiplicity of ecosystem services which biodiversity drives have also been severely compromised. This has compromised livelihoods and reduced human well-being. By linking the sustainable management of flood risk with the desire to deliver on multiple objectives consequently has the potential to provide solutions to both wetland loss and increased flood damage.

4 Every flood management project should be considered to not just restore degraded habitats but also to optimise opportunities for society to benefit from controlled flooding. The increasing awareness of and interest in ecosystem services over the last decade has placed the benefits society derives from natural systems at the top of environmental consciousness.

5 Against this changing landscape it is no longer acceptable for flood management practices to simply focus on reducing flooding and reducing the susceptibility to flood damage. Wider opportunities need to be considered.

6 Several tools and approaches have been developed to assist in understanding ecosystem services and to identify and value them. These tools, some of which have been reviewed in this paper, can be adapted and integrated in the development of flood risk management options. Society requires an ever increasing need for protection from flooding whilst demanding more from natural ecosystems. The integration of river and floodplain restoration with an enhancement of ecosystem services offers a rare opportunity to deliver win-win solutions.

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1 INTRODUCTION

1.1 Defining the problem

1.1.1 Traditional flood management

7 The traditional management response to a severe flood has typically been an ad hoc reaction – the quick implementation of a project that considered both the problem and its solution to be self- evident, and that gave no thought to the consequences for upstream and downstream flood risks. Thus, flood management practices have largely focused on reducing flooding and reducing the susceptibility to flood damage. Traditional flood management has employed structural and non-structural interventions, as well as physical and institutional interventions. Typical interventions include (WMO, 2009a):

- Source control to reduce runoff (permeable pavements, afforestation, artificial recharge);
- Storage of runoff (wetlands, detention basins, reservoirs);
- Capacity enhancement of rivers (bypass channels, channel deepening or widening);
- Separation of rivers and populations (land-use control, dikes, flood proofing, zoning, house raising);
- Emergency management during floods (flood warnings, emergency works to raise or strengthen dikes, flood proofing, evacuation); and
- Flood recovery (counselling, compensation or insurance: See IFM Tool on *Risk sharing*, WMO, 2009b).

8 Source controls seek to reduce the rate of runoff from rainfall or snowmelt, and usually concentrate of storing water in the soil upstream of areas of flood risk. This intervention normally considers the consequential effects on the erosion process, the time of concentration in the soil and the dynamics of evapotranspiration. The likely effectiveness of source control needs to also consider pre- flood conditions including the saturation status of the soil, and whether or not the ground is frozen. A potential drawback with some forms of source control, and other

forms of land-use modification which seek to reduce the rate of runoff such as afforestation, is that the capacity to absorb or store rainfall often depends on the antecedent conditions of the catchment which may be variable and difficult to manage.

9 The storage of surface water, utilising dams, embankments and retention or attenuation basins, is a traditional approach to managing flooding. Water storage can modify flood peaks by slowing the rate of rising waters, by increasing the time it takes for the waters to peak and by lowering the peak flood level, both in terms of velocity and volume. More often than not, surface water storage features serve multiple purposes, and flood storage can often be the first casualty in any conflict among purposes. Additionally, by virtually eliminating the low magnitude-high frequency floods, such measures can generate a false sense of security. For such interventions to be efficient, storage has to be used in an appropriate combination with other structural and non-structural measures. One aspect of storing surface water which should be self-evident, but is regularly overlooked in practice, is the need to make flood management a part not only of the planning and design, but also of the operation of reservoirs. Flood risks can occur as a result of releases from reservoirs; however the careful operation of reservoirs can also minimize the loss of human life and property due to such releases. An important aspect in relation to the design and management of reservoirs can be the consideration of transboundary cooperation.

10 Whilst increasing the carrying capacity of a river may seem to be a sensible response to the need to reduce flooding, the resultant changes to its natural morphological regimes can affect other river uses and has a tendency to simply shift the problem spatially and temporally rather than to eradicate it. Similarly, the deepening of channels may also generate undesirable impacts on the groundwater regime or on the energy regime of the river. Dikes or flood embankments are most likely to be appropriate for floodplains that are already intensely developed through urbanization, or where the residual risks of intense floodplain use may be easier to handle than the risks in other areas (from landslides or other disturbances, for example).

11 Land-use planning, zoning and control is generally adopted where intensive or inappropriate development on a particular floodplain is undesirable. Providing incentives for development to be undertaken elsewhere can be more effective than simply trying to stop development on the floodplain. However, where land is under development pressure, and especially from informal development, land-use control is less likely to be effective. Flood proofing or house raising are most appropriate where development intensities are low and properties are scattered, or where the warning times are short. In areas prone to frequent flooding, flood proofing of the infrastructure and the communication links can reduce the debilitating impacts of floods on the economy. For further information about flood proofing techniques, please refer to the IFM Tool on *Flood Proofing* (WMO, 2012).

12 Development of flood warning systems and the implementation of timely and robust emergency actions once flooding occurs are complementary to all forms of physical intervention. A combination of clear and accurate warning messages, with a high level of public awareness, can be invaluable and set the foundations for the best level of preparedness for self-reliant action during floods. Public awareness and education programmes are critical to ensure that the success of warnings intended to prevent a hazard from turning into a disaster. Evacuation is an essential component of emergency planning. Consideration of evacuation routes is essential and will usually include pathways to a flood refuge at a higher elevation or outward, depending upon the local circumstances. Outward evacuations are generally only necessary where the

depths of water are significant, where flood velocities are high and where the buildings are vulnerable. Without careful planning combined with an appropriate level of awareness among the wider population of what is required during a flood emergency flood evacuation and management plans can fail. It is essential that during the planning stage active community and stakeholder participation forms an integral component to the process and that regular exercises to assess the viability of the system are undertaken to ensure that genuine evacuations are effective. The provision of basic amenities such as water supply, sanitation and security in areas where refugees gather is particularly important in establishing a viable evacuation system.

1.1.2 Wetland loss, degradation and functioning

13 Floodplain and riverine wetland ecosystems include inter alia ponds, lakes, wet woodlands, wet grasslands, marshes and swamps. Many of these wetlands are naturally dynamic ecosystems, often as a result of periodic flooding and fluctuating hydrological regimes associated with rivers and their floodplains. For many of these wetland systems, flooding is the primary natural phenomenon which maintains their ecological functioning. For instance, inundation from flood events is often the principle conveyor of dissolved or suspended materials and nutrients into a wetland.

14 It is widely documented that wetlands, and especially those in floodplain environments, can deliver a wide array of hydrological and other services. For instance, swamps and lakes have been shown to assist with flood mitigation, promote groundwater recharge and regulate river flows (Bullock and Acreman, 2003). Similarly, the maintenance of the ecological functioning through routine flooding often sustains the delivery of the many benefits floodplain wetlands provide to millions of people, and particularly to those whose livelihoods depend on flood-recession agriculture and pasturage for fish production. For example, it has been estimated that in the Inner Delta of the Niger River an excess of half a million people with approximately one million sheep and one million goats use the floodplain for post-flood dry season grazing (Dugan, 1990).

15 Similarly, the Tonle Sap ecosystem in Cambodia is a major component of the Mekong basin, consisting of the Tonle Sap Lake, the Tonle Sap River and their surrounding floodplains. The Tonle Sap Lake is linked to the Mekong River through the 100 km long Tonle Sap River tributary (Lamberts, 2008). The Mekong River exhibits one of the largest natural flow variations throughout the year in the world. When water levels in the Mekong rise above a threshold level, which usually occurs in late May to early June, flow in the Tonle Sap River is reversed and Mekong water is pushed into the Tonle Sap River and Lake. Extensive flooding, lasting for up to five months, can result **(Figure 1)**. The floodwaters inundate vast floodplains and increase the Lake's water depth from about 0.5 to up to nine metres. This natural flood pulse drives a highly productive system where fisheries production is of particular interest as it provides directly and indirectly a livelihood basis for at least one million people (ADB, 2004).

16 However, flow alterations in the Mekong River are occurring as the result of completed, ongoing and planned development of over 30 hydropower generation structures, flood mitigation measures, navigation improvement interventions and overall increased abstraction and diversion of water, mostly for irrigation. All these activities will result in anthropogenic-induced alterations to the natural flow regime, which will have much further reaching implications. Dam construction is expected to attenuate flows resulting in the extreme water levels (low and high) becoming less extreme, generating more water in the dry season and less flood water

during the flow peak. Additionally, the construction of dams has the potential to alter the natural nutrient and sediment regime and also to form physical barriers to fish migration. The future consequence of changes to the natural flood dynamic for this important fishery are predicted to be negative leading to reduced human well-being and compromised livelihoods (ADB, 2004).

17 The catchment of the Charles River is one of the most densely populated river basins in North America. Urban and suburban development from Boston, Cambridge and surrounding communities has destroyed much of the lower river's wetlands and natural landscapes. This has resulted in a reduction of natural water storage and significant downstream flooding in 1938, 1955 and 1968 causing millions of dollars worth of damage. The United States Army Corps of Engineers commenced an analysis of the situation in the mid 1960s and discovered that wetlands still played a major role in storing excess floodwaters and reducing the potential for damage on the upper and middle portions of the Charles River. However, despite an understanding of their value, wetlands in Massachusetts continued to be degraded and lost at a rate of up to 1 percent per annum. The destruction of wetlands in the upper River Charles basin not only extended flooding problems throughout the catchment, it exacerbated flooding in the lower basin, as floodwaters, liberated from the buffering by wetlands, could move downstream more quickly.

18 In 1972, the Corps of Engineers commenced work to alleviate flooding in the lower basin by replacing the existing dam at the mouth of the river. A new dam and associated pumping station, which could divert high flows to Boston Harbour, was completed in 1978. The Corps' initial proposal for the basin also recommended the construction of levees and a second dam along the middle portion of the Charles River at an estimated cost of $100 million at 1970s prices. However, the 1968 flood had taught the Corps important lessons regarding the capacity of the wetlands to store flood waters. Based on an understanding of the capacity of wetlands to attenuate flooding, in 1977 the Corps began purchasing land and acquiring easements, prioritizing parcels by location, storage capacity and threat of development. By 1983, the Corps had purchased approximately 1,300 hectares and acquired easements on 1,975 hectares of private land. The protected area now includes over 75 percent of all existing wetlands in the Charles River watershed (American Rivers, 2012). In addition to the wildlife, recreational and economic benefits which have resulted from the protection of wetlands, estimates have suggested that the capitalized flood control value of wetlands within the Charles River basin was approximately $5,000 per wetland hectare at 1981 prices (Thibodeau and Ostro, 1981).

19 The example from Tonle Sap illustrates the case that natural floodplains are amongst the most biologically productive and diverse systems on earth and the Charles River wetland study demonstrates the huge benefits wetlands can bring to communities through flood attenuation. However, despite this, a key question remains: if it is established that wetland ecosystems, including those associated with rivers and their floodplains, provide a range of benefits, why does wetland loss and degradation continue? It is, to some degree, understandable that flat, fertile land and ease of access has drawn agriculture, industry and urban settlement to floodplain areas, consequently displacing natural habitats. When large areas of wetlands exist, the marginal cost to society of displacement can be relatively low. However, as wetland loss progresses and more and more natural floodplain habitats are lost this penalty increases. Whilst some of the land use changes can be in society's best interest, when the returns from that land use are relatively high, more often or not the conversion of wetlands only result in a limited gain or even a net cost to society. This loss can often be attributed to inter-related market and

intervention failures, exacerbated by a lack of information and understanding of the full value of the multitude of functions that wetlands provide (Turner and Jones, 1991).

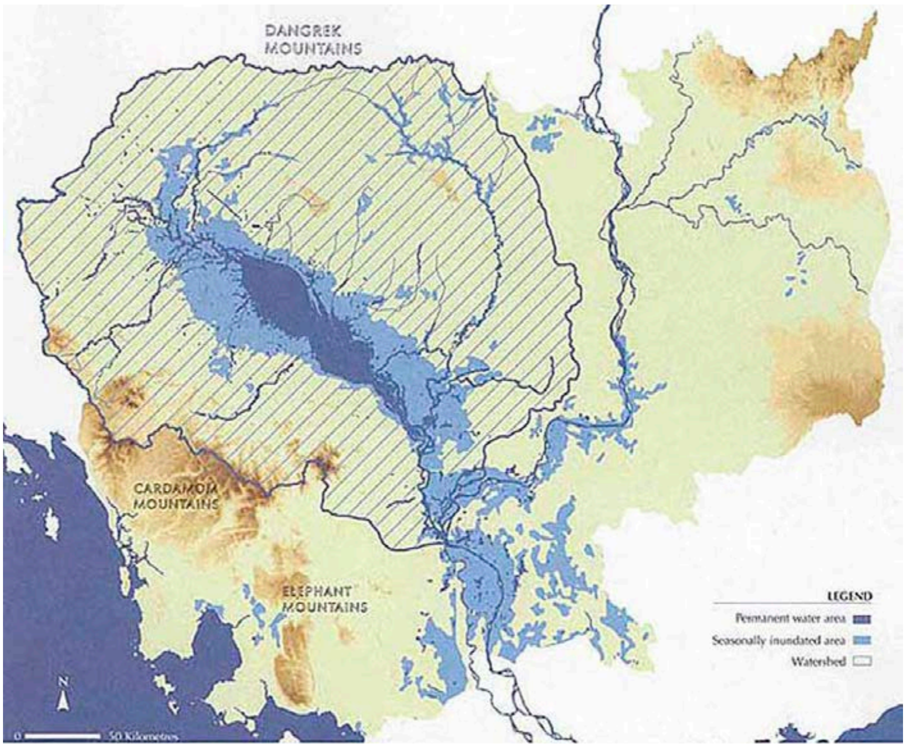

Figure 1 — Cambodia map - seasonal variation Tonle Sap
(Courtesy of Andrew J Booth - www.aboutasiatravel.com)

20 Wetland loss and degradation has been significant. Estimates have suggested that in Europe and North America up to 90% of natural floodplain wetlands have suffered from habitat alteration, flow and flood control, species invasion and pollution and can now be considered as functionally extinct (Tockner and Stanford, 2002). Similarly, it is widely accepted that more than 50% of specific types of wetlands were destroyed in parts of North America, Europe, Australia, and New Zealand during the twentieth century. Many other wetland systems continue to be degraded across the globe. The publication of the IUCN Red List of Threatened Species in 2009 demonstrated the continued impacts on rivers and their associated wetland systems. It is estimated that 37% of freshwater fish species and 30% of all amphibian species are threatened with extinction (IUCN, 2009). Disturbingly, the Millennium Ecosystem Assessment (MA) reported that the degradation and loss of wetlands, and the deterioration of freshwater and coastal wetland species, are more rapid than that of other ecosystems (Millennium Ecosystem Assessment, 2005a).

1.1.3 Scope and structure

21 The central theme of this paper is to demonstrate that through the conservation and restoration of rivers and floodplains it is possible to provide sustainable flood risk management as well as optimising a range of other benefits associated with these important wetland systems. It will be argued that traditional approaches to flood management have not always succeeded in reducing flooding and susceptibility to flooding, but to compound this failing they have also compromised the delivery of the important benefits that natural floodplains can provide. These

benefits, or ecosystem services (Millennium Ecosystem Assessment, 2005a), are traditionally poorly considered in decision-making resulting in missed opportunities to deliver on multi-functional flood management solutions which can benefit a multitude of stakeholders.

22 It is not the intention of this paper to provide a technical manual on how to identify and consider every possible ecosystem service associated with restoring or conserving rivers and floodplains as an aspect of sustainable flood management, rather it sets out a conceptual framework and an approach for consideration. The main audience for this paper is cross-sectorial including the usual target groups such as municipal authorities, national and local flood management planners, flood risk management regulatory bodies, and river managers. However, in order to ensure that multiple objectives are considered and flood management is more widely recognised as an opportunity to deliver benefits across a range of sectors, this paper should have resonance with agricultural, nature conservation, water resource, recreation and tourism, carbon management and human health sectors to name but a few.

23 As the concept of ecosystem services is still misunderstood in some sectors and the language associated with it potentially confusing and inaccessible, **Chapter 2** provides an overview of the concept, linking both the ecosystem approach and ecosystem services to human well-being and explaining the importance of demonstrating the economic benefits of rivers and their associated wetlands. **Chapter 3** discusses the issues relating to the aspiration to deliver on multiple objectives and presents a conceptual framework in order to take this approach forward. **Chapter 4** summarises the key recommendations for the conservation and restoration of rivers and floodplains in order to serve multiple objectives in managing floods.

2 WETLAND ECOSYSTEM SERVICES

2.1 The ecosystem approach and ecosystem services

2.1.1 Origins of the concept

24 The term 'ecosystem' was first applied in the 1930s (Tansley, 1935), however the concept had been around since the beginning of the nineteenth century, if not earlier. Many differing definitions abound as to what is an ecosystem. A useful, relatively early definition of an ecosystem is a:

> *"functioning, interacting system composed of one or more living organisms and their effective environment, both physical and biological. The description of an ecosystem may include its spatial relations, inventories of its physical features, its habitats and ecological niches, its organisms and its basic reserves of energy and matter, the nature of its income of matter, and energy and the behaviour or trend of its entropy levels"*
> (Fosberg, 1963).

25 The ecosystem model has become a fundamental approach for viewing and understanding the natural world, and also the anthropogenic influences on it. It is predicated on identifying and considering the functional links between species or groups of species, such as across trophic levels as in food webs, and between organisms and their environment, such as habitat niche requirements and tolerances to environmental variables such as climate or hydrological regime. Flows of energy, nutrients and materials, such as water or sediments, interact to maintain the ecosystem structure, stability and biological diversity.

26 However, the concept of an 'ecosystem' has been subject to divergent thinking ever since its inception. The basic division is between those who recognised a 'concrete' existence of an ecosystem, and consequently used and interpreted the term solely to describe discrete ecological units such as a forest or an island, and those whose emphasis was on using the term to present 'conceptual models' of reality (Maltby et al., 1999).

27 The 'concrete' application of the term presupposes that the complexity of the interactions among the various elements of, for instance, a grassland ecosystem, are defined and established. Whereas, at best, only estimates of the major flows of matter and energy, often over limited periods of observation, exist. Often the research required to move beyond this is expensive and consequently preclusive. Nevertheless, the ability to recognise tangible or relatively discrete units of land or water as ecosystems that possess differences in the way they function is a potentially powerful concept, especially for interactive management. The alternative, 'conceptual', approach understands that boundaries between different land or water elements are essentially artificial constructs applied to simplify reality. Hence the application of this approach centres on the conceptual basis to advance the research, understanding and management of the natural world rather than the practical use for delineating entities in the field.

28 The adoption of ecosystem thinking allows consideration of complex interactions among plant, animal and human elements to be brought together under a single framework. The thinking is essentially holistic and should also be structured. Ecosystem elements can be arranged in a hierarchical structure that assists in the interpretation of relationships and dependencies and also benefits the organisation and analysis of data. Key to understanding relationships is the emphasis on 'functioning' which enables the factors affecting different elements within a system to be recognized and relationships among components to be understood.

29 Since the 1940s there has been progressive development and emphasis on both the scientific study of ecosystems and the potential application of an ecosystem concept as a policy tool. Prompted by observed degradation in many ecosystems, the idea of 'ecosystem management' began to develop a broad acceptance in the early 1980s in the United States as a way to better manage natural resources. This conceptual thinking evolved into the term 'ecosystem approach' in order to describe a particular form of environmental management. In the United States an Inter-Agency Ecosystem Management Task Force defined the ecosystem approach as 'a method for sustaining or restoring natural systems and their functions and values. It is goal driven, and it is based on a collaboratively developed vision of devised future condition that integrates ecological, economic and social factors. It is applied within a geographic framework defined by ecological boundaries' (Inter-Agency Ecosystem Management Task Force, 1995).

30 At the second Conference of the Parties (COP) to the Convention on Biological Diversity (CBD), held in Jakarta, November 1995, the Parties adopted the ecosystem approach as the primary framework for action under the Convention, and subsequently has referred to the ecosystem approach in the elaboration and implementation of the various thematic and cross-cutting issues work programmes under the Convention (Convention on Biological Diversity, 1995). CBD define the ecosystem approach as: *"a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way"*.

31 CBD recognises that the application of the ecosystem approach will help to reach a balance of the three objectives of the Convention: namely conservation; sustainable use; and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. The approach is based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity,

are an integral component of ecosystems. Underpinning the implementation of the ecosystem approach are twelve underlying principles **(Box 1)** and related operational guidance **(Box 2)**.

32 Explicit in the implementation of the ecosystem approach is the need for cross-sectoral linkages through integration into agriculture, fisheries, forestry and other production systems that have an effect on biodiversity. The management of natural resources, according to the ecosystem approach, calls for increased inter-sectoral communication and cooperation at a range of levels (government ministries, management agencies, etc.). This requirement extends to the management of flooding and the development of appropriate management strategies.

Box 1 — 12 Principles of the CBD Ecosystem Approach

The following 12 principles are complementary and interlinked:

1. The objectives of management of land, water and living resources are a matter of societal choices.
2. Management should be decentralized to the lowest appropriate level.
3. Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.
4. Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context.
5. Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.
6. Ecosystem must be managed within the limits of their functioning.
7. The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.
8. Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.
9. Management must recognize the change is inevitable.
10. The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.
11. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.
12. The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Box 2 — Five points of operational guidance for applying the CBD Ecosystem Approach

In applying the 12 principles of the ecosystem approach, the following five points are proposed as operational guidance:

1. Focus on the relationships and processes within ecosystem.
2. Enhance benefit-sharing.
3. Use adaptive management practices.
4. Carry out management actions at the scale appropriate for the issue being addressed, with decentralization to lowest level, as appropriate.
5. Ensure inter-sectoral cooperation.

2.1.2 Processes, functions and ecosystem services

33 **Principle 5** of the ecosystem approach states that the: *"conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach"*.

34 All ecosystems are composed of physical, biological and chemical components such as soil, water, plants and animals (Maltby et al., 1996). Interactions among and between these elements allow the ecosystem to perform a range of 'functions' **(Figure 2)**. The functions are dependent on the processes and structure of the ecosystem. Ecosystem functions have been defined as the capacity of ecosystem processes and components to provide goods and services that satisfy human needs, directly or indirectly (de Groot, 1992). Ecosystem services are defined by the Millennium Ecosystem Assessment (MA) as: "the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious, and other nonmaterial benefits" (Millennium Ecosystem Assessment, 2005a).

35 Wetland ecosystems, including rivers and floodplains, have long been recognised as providing a range of benefits for people and society. The Ramsar Convention on Wetlands has promoted the wise use of wetlands as a means of maintaining their ecological character and the ecosystem processes and structure which underpin the delivery of ecosystem services. Increasingly the valuation of ecosystem services is seen as important in making more informed decisions regarding the use and management of wetlands and their benefit to society (Barbier et al., 1997). Because of the many services and multiple values of wetlands, many different stakeholders are involved in wetland use. This can lead to conflicting interests and the over-exploitation of some services (e.g., fisheries or waste disposal) at the expense of others (e.g., biodiversity conservation or nutrient removal) (Hansson et al., 2005).

36 However, despite a wealth of clear evidence acknowledging that wetlands provide a range of benefits, there are still considerable challenges in developing an approach which delivers on multiple objectives and successfully optimises ecosystem service delivery, as is the case with traditional flood management.

37 The MA categorises ecosystem services into four broad areas: provisioning, regulating, cultural and supporting. Each service possesses sub-categories. For instance regulating includes, among others, climate regulation, water regulation, water purification and waste treatment, erosion regulation and natural hazard regulation **(Box 3)**.

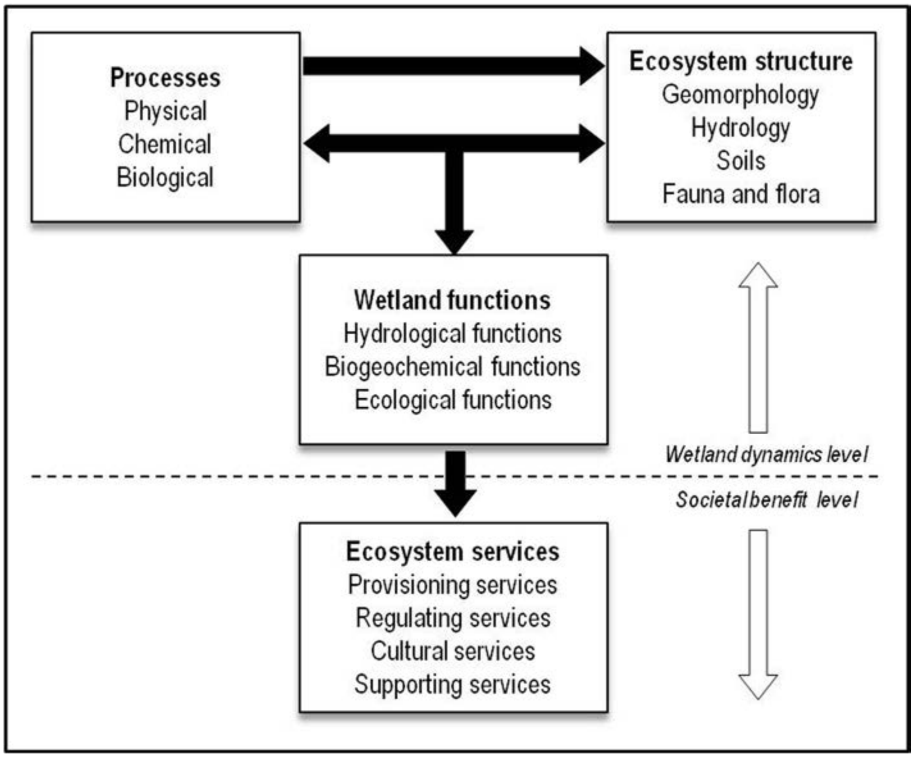

Figure 2 — Wetland ecosystem processes, functions and structure (adapted from *Maltby et al., 1996)*.

38 The degree to which a wetland delivers ecosystem services depends on its functional properties (e.g., processes and structural components) and relationship between and among ecological components and processes **(Figure 2)**. However, it is important to understand distinctions between the different components of the 'ecosystem services paradigm'. It is also of paramount importance to understand the societal and spatial context. **Figure 2** indicates that a wetland may have the capacity, i.e. it possesses the appropriate biophysical structure and supports the necessary processes which combine to produce a function, however it does not always follow that society perceives a benefit (value) for the delivery of the service, i.e. water purification and waste treatment. People and society will value functions differently in different places at different times (Haines-Young and Potschin, 2007). Therefore in defining what constitutes an ecosystem service it is important to understand the societal, spatial and temporal context.

39 **Figure 3** illustrates how an individual ecosystem service – regulating – can comprise a variety of subcategories which can be driven by a range of functions all of which are maintained by processes. Each process is in turn maintained by a range of controlling variables. For instance, in the case of regulating water quality through water purification and waste treatment, a range of functions operate to deliver on the overall ecosystem service. These functions include the removal and retention of a range of water-borne pollutants and contaminants. The processes supporting these functions result in removal of the pollutant from a wetland or the temporary or permanent retention of the pollutant within a wetland. For instance, wetlands can remove nitrogen from surface waters preventing eutrophication and water pollution issues. Wetlands

can also retain and remove nitrogen from surface waters through a range of different processes including plant uptake of nutrients, gaseous removal through denitrification or storage in organic matter. All of these individual processes are controlled by a range of environmental variables including inter alia soil properties, climate, vegetation, hydrology, land use and type and rate of nitrogen input. This approach to breaking down an ecosystem service into its constituent functions, processes and controlling variables underpins a large body of research work undertaken to understand and predict the functions performed by wetland ecosystems.

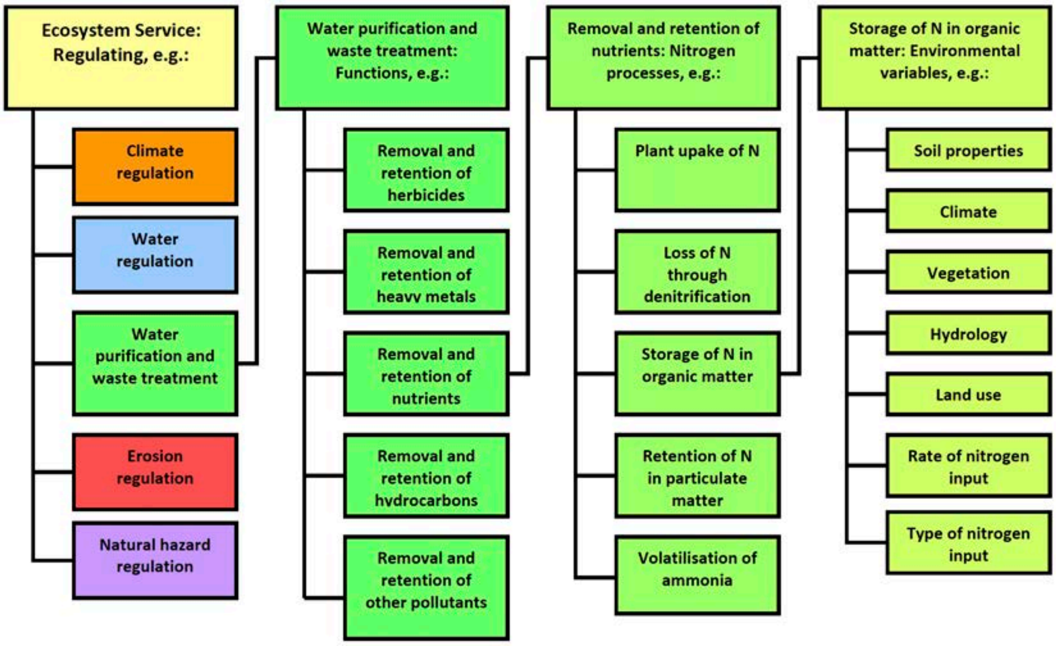

Figure 3 — Relationships among ecosystem services, functions and processes: example for removal and retention of nitrogen as a component of the regulating ecosystem service (modified from *McInnes et al., 2008*).

40 The ability to aggregate and disaggregate ecosystem services to ensure that opportunities can be understood and identified is essential if flood management strategies are to deliver multiple benefits. Such an approach allows decision-makers and stakeholders alike to understand that the management of flood waters can alter the various processes which drive functions and subsequent ecosystem service delivery. If this management does not consider the implications, both positive and negative, then benefits derived from certain ecosystem services could be compromised.

2.2 Ecosystem services and human well-being

2.2.1 Linking ecosystems and human well-being

41 The MA starkly concluded that human activity is placing such a strain on the natural functions of the Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted (Millennium Ecosystem Assessment, 2005b). It went on to say that the provision of food, fresh water, energy, and materials to a growing population has come at considerable cost to the complex systems of plants, animals, and biological processes that make the planet habitable. As the demands of humans continue to increase over the coming

decades ecosystems will face ever greater pressures potentially weakening further the natural infrastructure on which human society depends.

42 The MA further recommended that in order to protect and improve the future well-being of humanity the natural environment must be considered as an asset that requires wiser and less destructive use. To achieve this it is necessary to recognize the true value of nature, both in an economic sense and in the richness it provides to society. It is also necessary to consider as a priority, and not as an optional extra, the conservation of ecosystem structure and functioning, in order to maintain ecosystem services. Implicit in this is the need to restore or reanimate ecosystem functioning in order to stimulate the delivery of ecosystem services.

43 In the context of ecosystem services human well-being is defined by the MA as having:

> *"multiple constituents, including basic material for a good life, freedom and choice, health, good social relations, and security. Wellbeing is at the opposite end of a continuum from poverty, which has been defined as a "pronounced deprivation in well- being." The constituents of well-being, as experienced and perceived by people, are situation-dependent, reflecting local geography, culture, and ecological circumstances".*

44 Over the last century, as the demands for food, fresh water, fibre and energy have continued to increase the resultant changes to the natural world have been without precedent. Undoubtedly some of these changes have helped to improve the quality of the lives of billions, but at the same time they weakened nature's ability to deliver other key services. This has included significant changes in the ability of ecosystems to provide clean water or to protect human society from disasters such as flooding. As a consequence, the well-being of many people has been seriously compromised.

45 Three important messages have emerged from the analysis undertaken by the MA. First, protection of nature's services is unlikely to be a priority so long as they are perceived to be free and limitless by those using them. Effective policies need to take into account the costs of the benefits provided by ecosystem services in all economic decisions. Secondly, local communities are far more likely to act in ways that conserve natural resources if they have real influence in the decisions on how resources are used and, possibly of greater significance, if they end up with a fairer share of the benefits accruing. Finally, natural assets will receive far better protection if their importance is recognized in the central decision-making of governments and businesses, rather than leaving policies associated with ecosystems to relatively weak environment departments. Or in other words, the protection and appropriate management of natural resources is not the sole responsibility of traditional environmental managers but needs to be embedded across a range of policies and sectors, including the sustainable management of flooding.

46 Therefore the traditional approach to flood management, through reducing flooding and decreasing the susceptibility to flood damage, needs to go further to consider how the delivery of ecosystem services can be achieved in order to improve human well-being in a multidimensional manner.

2.2.2 Standard nomenclature for ecosystem services

47 One of the benchmark outputs of the MA was to generate a standard nomenclature for describing the benefits which nature provides. The division of ecosystem services into provisioning, regulating, cultural and supporting services (see **Box 3**) has been widely adopted and, whilst local variants do exist, the terms have entered the colloquial lexicon. This has generated both positive and negative responses.

48 Some authors have contested that if ecosystem services are to provide an effective framework for natural resource decisions, they must be classified in a way that allows comparisons and trade-offs amongst the relevant set of potential benefits. In MA terms this means that the full range of benefits reflecting human well-being from ecosystems must be represented in any effective typology of ecosystem services (Wallace, 2007). However, it has been argued that the MA classification of ecosystem services mixes processes (means) for achieving services and the services themselves (ends) within the same classification category. For instance a land manager who might be interested in growing an agricultural crop wants as his or her output (or 'ends') to produce rice. However in order to achieve this there is a requirement for inter alia pollination, biological control and water regulation, which are not ends but rather means to an end. Therefore the land manager will manage these means to the degree necessary to deliver on the final ends, in this case rice.

49 Thus the set of services as described in **Box 3** may not be fully coherent and representative of a same level of output. Consequently, whilst the common lexicon has a wide level of awareness, to the more informed, the MA classification presents inherent problems for decision-makers. One of the issues this exposes is that care must be taken when considering trade-offs between ecosystem services to ensure that assumptions are robust.

50 However, whilst the MA typology for ecosystem services can be considered neither perfect nor complete it does provide a broadly inter-comparable set of services which can be applied across bioregions and ecosystem types. Furthermore, the use of consistent terms allows a degree of transferability across different sectors who might otherwise not be party to discussions regarding the management of flooding.

Box 3 — Ecosystem services provided by or derived from wetlands

Provisioning Services: The products obtained from ecosystems, including:

- *Food and fiber:* This includes the vast range of food products derived from plants, animals, and microbes, as well as materials such as wood, jute, hemp, silk, and many other products derived from ecosystems.
- *Fuel:* Wood, dung, and other biological materials serve as sources of energy.
- *Genetic resources:* This includes the genes and genetic information used for animal and plant breeding and biotechnology.
- *Genetic resources:* This includes the genes and genetic information used for animal and plant breeding and biotechnology.
- *Biochemicals, natural medicines, and pharmaceuticals:* Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.

Box 3 — Ecosystem services provided by or derived from wetlands (cont'd)

Provisioning Services: *(cont'd)*

- *Ornamental resources:* Animal products, such as skins and shells, and flowers are used as ornaments, although the value of these resources is often culturally determined. This is an example of linkages between the categories of ecosystem services (provisioning and cultural).
- *Fresh water:* Fresh water is another example of linkages between categories – in this case, between provisioning and regulating services.

Regulating Services: The benefits obtained from the regulation of ecosystem processes, including:

- *Air quality maintenance:* Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.
- *Climate regulation:* Ecosystems influence climate both locally and globally. For example, at a local scale, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.
- *Water regulation:* The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.
- *Hydraulic Regulation:* Wetland vegetation also reduces high flow velocities during floods, diminishing erosion and damage to structural defences (dams, levees, embankments, etc.)
- *Erosion control:* Vegetative cover plays an important role in soil retention and the prevention of landslides.
- *Water purification and waste treatment:* Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems.
- *Regulation of human diseases:* Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.
- *Biological control:* Ecosystem changes affect the prevalence of crop and livestock pests and diseases.
- *Pollination:* Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
- *Storm protection:* The presence of coastal ecosystems such as mangroves and coral reefs can dramatically reduce the damage caused by hurricanes or large waves.

Cultural Services: The nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including:

- *Cultural diversity:* The diversity of ecosystems is one factor influencing the diversity of cultures.
- *Spiritual and religious values:* Many religions attach spiritual and religious values to ecosystems or their components.
- *Knowledge systems (traditional and formal):* Ecosystems influence the types of knowledge systems developed by different cultures.
- *Educational values:* Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.
- *Inspiration:* Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
- *Aesthetic values:* Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, "scenic drives," and the selection of housing locations.

Box 3 — Ecosystem services provided by or derived from wetlands *(cont'd)*

Cultural Services: *(cont'd)*

- *Social relations:* Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.
- *Sense of place:* Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.
- *Cultural heritage values:* Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species.
- *Recreation and ecotourism:* People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

Supporting services: Those that are necessary for the production of all other ecosystem services and include:

- *Soil formation:* The retention of sediments and the accumulation of organic matter.
- *Nutrient cycling:* The storage, recycling, processing and acquisition of nutrient.

2.2.3 Considering trade-offs among ecosystem services

51 Despite the potential inconsistencies in the list of ecosystem services, the awareness that the natural environment provides a range of services has lead to great enthusiasm for win–win solutions in the conservation-and-development debate. This debate extends logically to the development of flood management strategies.

52 The unfortunate reality is that in a world that is increasingly resource-constrained, increases in one ecosystem service can typically result in the reduction in other services. This has been reflected in the traditional approach to managing flooding, where consideration of a full range of ecosystem services is routinely overlooked at the expense of structural interventions. Many conservation bodies would argue that the benefits provided by historical flood management projects, which have truncated the natural flood pulse required to support floodplain functioning, have emphasized a regulating service at the cost of a range of other provisioning or cultural services.

53 Conversely, over the last century as the demands on the natural world to provide for human society and the overall increase in provisioning services, as typified by intensification of farming, has been achieved at the expense of decreases in regulating and cultural services, and, ultimately, biodiversity.

54 In order to develop more sustainable and multifunctional solutions it is necessary to consider simultaneously multiple ecosystem services and multiple beneficiaries, not just to obtain a more complete understanding of the benefits and losses, but because a change in any one ecosystem service might be related, either positively or negatively, to other services.

55 An example of this issue has been developed to illustrate the potential issues associated with ecotourism (Tallis et al., 2008). **Figure 4** demonstrates the potential trade-offs which can arise in

a project. For example, developing ecotourism can bring direct income to local communities which in turn generates an improvement of community stewardship of the natural environment in order to protect the features of ecotouristic interest (e.g., biodiversity for wildlife viewing or sports fisheries), This provides a win–win situation for nature and people **(Figure 4b)**.

56 Alternatively, the excessive development of infrastructure to support the tourism, or excessive tourism activities such as hiking and fishing, can compromise the very resources which attracts tourists in the first place, resulting in a lose–lose situation **(Figure 4a)**. An example of this is the rapid development of trekking in Nepal which has resulted in the unsustainable harvesting of firewood, thereby degrading local ecosystems. A range of potential outcomes exist, depending on how people manage ecosystems as the intensity of use changes, resulting in win-win, lose-lose, or trade-off outcomes **(Figure 4c)**.

2.3 Examples of regulation of flooding and river restoration

57 A synthesis of the restoration of stream ecosystems produced in the mid 1990s stated that:

> *"it is possible to bring nature conservation and ecosystem benefits across whole catchments. To do this the disparate interests along the whole of the stream must be considered. Normally it is not possible to meet all needs and demands at the same time. Society has to choose its priorities"*
> (Nielsen, 1995).

58 Embedded within this philosophy is the need for society to balance the trade-offs among ecosystem services related to the restoration of rivers, streams and their floodplain. This approach is expanded further in the Changwon Declaration on human well-being and wetlands, which formed a resolution of the meeting of the Contracting Parties of the Ramsar Convention in 2008 and stated that:

> *"wise use, management and restoration of wetlands should help to build opportunities for improving people's livelihoods, particularly for wetland-dependent, marginalised and vulnerable people*
> (Ramsar Convention. 2008).

59 Therefore the conservation and restoration of rivers and floodplains should seek to balance the inherent trade-offs that exist and ensure that in doing so livelihoods are improved. The following section reviews several approaches to developing flood management strategies which have tried to identify and balance the conflicting needs of society whilst reducing flood risk.

2.3.1 The River Skerne, UK

60 An example of working with local communities in order to balance potential trade-offs has been implemented within the United Kingdom. The European Union funded river restoration project on the River Skerne near Darlington in north east England was carried out specifically to demonstrate and assess the use of more natural processes in flood risk management and at its heart was the desire to involve the local community in the design, construction and future monitoring.

61 Over the previous 200 years the River Skerne had been straightened and deepened. Much of the floodplain has been raised high above the river by industrial waste tipping. Housing developments and infrastructure such as gas pipelines had further compromised the floodplain environment and severed the connection between the river channel and the floodplain (River Restoration Centre. 1998). This situation is typical of many river systems in the United Kingdom and beyond.

62 The objectives of the scheme were to restore a 2km reach of the river and its floodplain in terms of physical features and to deliver on a range of ecosystem services including flood management, habitat diversity, water quality, landscape and access for the local community. Secondary objectives included the opportunity to apply innovative river restoration techniques within an urban environment and to further the knowledge and understanding of river restoration through a comprehensive monitoring programme.

63 The scheme involved remeandering sections of the river, cutting a new channel and back-filling the old, straightened channel, reprofiling the river banks and lowering the floodplain surface to increase flood storage. The local community were actively engaged in the design, planning and implementation of the project to ensure that the resultant benefits of the scheme reached the appropriate stakeholders. The monitoring programme, established as one of the original objectives, has discovered that the improved urban environment around the River Skerne has provided significant quality of life benefits to the local community. Key benefits delivered to the local community include an increase in wildlife, improved landscape quality and reduced risk of flooding.

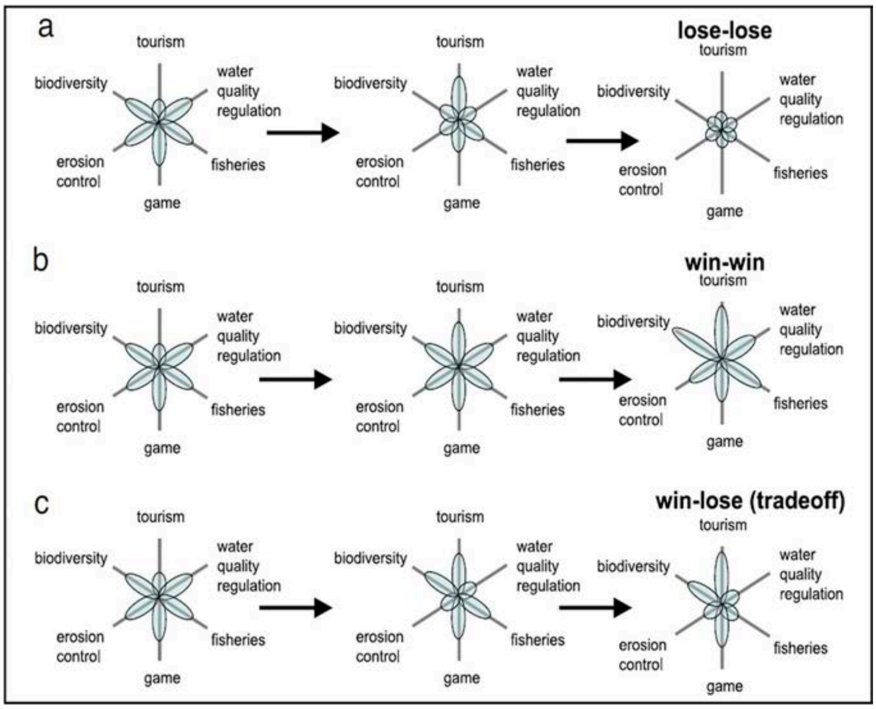

Figure 4 — "Trade-off flowers" depicting alternative scenarios for ecotourism projects aimed at biodiversity protection and economic growth: (a) unrestrained ecotourism can lead to infrastructure and human traffic that degrades many ecosystem services, and ecotourism itself collapses; (b) ecotourism develops with good management of biodiversity and ecosystem services, so that income flows from tourism, biodiversity is enhanced, and ecosystem services are not lost; (c) ecotourism develops and biodiversity is protected in nature reserves, but the increase in roads and hotels undermines water quality and fisheries, causing tradeoffs among ecosystem services and development (reproduced from *Tallis et al., 2008).*

2.3.2 The Rhine Delta, Netherlands

64 On a larger scale, the River Rhine Delta represents one of the most densely populated areas in the Netherlands and is under considerable flood risk. The numerous rivers of the delta flow via various routes to the North Sea. One such route is to the north via the river Ijssel and the Ijssel Lake. A second route is through the Lower-Rhine and River Lek, passing through the city and the harbour area of Rotterdam before reaching the sea. The third, and principal watercourse is the river Waal, which flows through the estuaries in the southern part of the delta and reaches the North Sea through the sluices of the storm surge barriers of the Delta Works. For the last stretch, the Waal is joined by the river Meuse, which enters the Netherlands south of Maastricht.

65 The area of land available for these various rivers has decreased continually during the past centuries. The rivers have become confined by increasingly higher dikes (or flood embankments). Behind the dikes the population density has continued to increase. At the same time the land behind the dikes has sunk due to settlement and soil subsidence. It has been estimated that a breach in one of the dikes could place approximately four million Dutch citizens in danger from flooding.

66 Starting in 2002, the Dutch Government has worked with a total of 17 partners drawn from the provinces, municipalities, water boards and Rijkswaterstaat to develop an integrated plan for the sustainable management of flood risk in the Rhine Delta which also balances the needs and demands of a densely populated conurbation. Overall responsibility for the project, termed the *Room for the Rivers* Programme, lies with the Minister of Transport, Public Works and Water Management. The Programme, which will operate from 2007 until 2015, is investing not just in reducing the risk of flooding but also in environmental quality by making the rivers region more attractive and appealing to the public and offering more room to nature conservation and recreation (Room for the River, 2007).

67 In ensuring the Lower Rhine and River Meuse can cope with predicted discharges of up to 16,000m^3/sec and 3,800m^3/sec respectively by the year 2015, a series of measures are being implemented in an integrated approach to river management planning. These measures include:

- Relocation of dikes: Dikes will be relocated at a distance from the river banks creating additional space within the flood plain for the river during annual flood events;
- Lowering the floodplain: In addition to the relocation of the dikes, the floodplain will be excavated and the overall elevation lowered in order to remove sediments which have been progressively deposited as a result of regular flooding;
- Increasing the width of the floodplain: Embankments will be relocated to allow the active floodplain area to be widened and storage of water increased;
- Reduce height of the groynes: Groynes which currently stabilize the position of the river also act as obstacles to flow. Many groynes will be lowered to facilitate more rapid drainage;
- Depoldering: Dikes on the river side of a polder will be relocated inwards effectively 'depoldering' and allowing water to flood area at high water levels;
- Construction of a 'Green Channel': A new river or 'Green Channel' will be constructed to serve as a flood bypass;

– Increasing the depth of the summer river bed: The river bed will be deepened to increase the capacity of the river. It will also allow for more water to be removed from the flooded location thus reducing the breach of the dikes;

– Removal of obstacles: Locations along the river where there are obstacles to flood flows will be addressed and where appropriate these will be removed;

– Strengthening of dikes: Where making more room for the river is not an option then dikes will be strengthened.

68 The end result of the *Room for the River* programme will be a more resilient river system with areas of floodplain functioning in a more naturalistic manner and an enhanced environment which will provide several benefits to the large local population.

69 However, the examples of the River Skerne and the Rhine Delta focus on trying to integrate flood risk management demands with wider societal benefits along a reach, or an extended reach in the case of the Rhine Delta, rather than attempting to address issues on a catchment scale. This is a common issue in the management of flood risk. Often the desirability to adopt a 'basincentric' approach is compromised by numerous factors including the difficulties involved in addressing trans- boundary governance, the multiplicity of stakeholders and the various different hydrological regimes which may exist across a river basin.

2.3.3 Saguenay and Red River valleys, Canada

70 Despite these potential barriers, attempts have been made to address this situation. For instance in Canada, following significant floods in the Saguenay and Red River valleys in Manitoba and concerns regarding reductions in public funds, a critical review of flood management concluded that traditional approaches, whilst providing some considerable successes, had failed to consider three essential elements of an ecosystem approach. Consequently, traditional approaches have not delivered robust, integrated or sustainable flood management (Shrubsole, 2000).

71 The first criticism of the traditional approaches to flood management in Canada was the propensity to take a 'rivercentric' rather than a 'basincentric' viewpoint, effectively using an incorrect conceptual ecosystem appropriate for the issue under consideration. Whilst this may sometimes be the only practical option available, such as with the example of the River Skerne or the Rhine Delta, focussing attention on the main river and its immediate floodplain within Canada was seen to compromise the consideration of the impacts and appropriate mitigation measures that are associated with agricultural drainage and other land use changes. An additional consequence of the rivercentric view has been the exclusion of consideration of drainage projects, ice jams and overland flow as contributors to, or causes of, flooding. The rivercentric focus within Canada was considered to have also generated a relatively narrow set of flood management responses. A basincentric approach, which adopts a conceptual construct that considers the watershed as the appropriate ecosystem for understanding and managing flood risks, would increase the range of potential solutions and promote the consideration of a broader set of flood sources and hazard types. When appropriately considered, the basincentric approach should emphasize how a wider range of human activities can be accommodated through a better understanding of watershed-scale processes.

72 Although the adoption of a basincentric approach was considered to represent an improvement over traditional practice, based on the Canadian experience, the focus on human activities

could be perceived as a weakness. By adopting an 'ecocentric' approach, more consistent with the ecosystem approach, the objective would be to manage and restore floodplains, river channels and watershed biodiversity in a manner that enhances both the quality of the natural environment and human well- being. Such an approach requires the flood regulating service and other benefits delivered by watersheds to be considered and valued in a systematic manner so that they are adequately considered in the decision-making mechanisms. The Canadian review recommends the use of the term 'infrastructure' to embrace both man-made and natural features and that the implementation of an 'ecocentric' approach should seek to cooperate with nature rather than work against it.

73 A third aspect of the Canadian review focused attention on integrated institutional arrangements and the fragmented approach to permitting activities, such as for reservoirs, water structures, agricultural drainage and land development, which failed to allow ecosystem managers to consider the effects of these activities on the ecosystem. These shortcomings highlight the need for institutional reform, which should include the development of new institutional arrangements based on a greater sharing of responsibilities, particularly between the provincial government and municipalities, but also that should extend to the agencies that have responsibilities for flood prevention and those that focus on preparedness, response and recovery. Such a level of institutional integration was infrequently considered in the Canadian context and is often the case elsewhere in the world.

2.3.4 Engelberg Aa River, Switzerland

74 A similar integrated approach is advocated in Switzerland. In collaboration, the Swiss Agency for the Environment, Forests and Landscape (SAEFL), the Federal Office for Water and Geology (OFEG), the Federal Office for Agriculture (FOAG), and the Federal Office for Spatial Development (OSD)[1] have produced *"Guiding Principles for Swiss watercourses"* (SAEFL, FOWG, 2003). These describe the goals for the development of watercourses and adopt an integrated approach which promotes sustainable watercourse management at all levels.

75 The emphasis of the Swiss Guiding Principles is on the following three development goals: *(1)* adequate space for watercourses; *(2)* adequate water flows; and *(3)* adequate water quality. It is advocated that these three goals can be achieved by giving equal weight to the social, ecological and economic aspects of watercourse management. However, the Guiding Principles also recognise that if there is to be effective delivery these goals can only be achieved by means of interdisciplinary co- operation among specialists in the fields of river engineering, ecology, spatial and landscape planning and agriculture. Whilst each separate specialism will approach the issues from their own perspective, collectively there should be the recognisable view that all potentially competing interests need to be appropriately and fairly considered in order to deliver a sustainable outcome. A key factor in this delivery is the collaboration between the federal, cantonal and communal agencies.

76 The implementation of the Guiding Principles has been embraced by the canton of Nidwalden in its flood management project for the Engelberg Aa River on the southern shore of Lake Lucerne. The objective was not to prevent flooding at any cost, rather the degree of protection has been modified in relation to the value and significance of the assets to be protected.

1 SAEFL and OFEG were merged on 1st January 2006 into the Federal Office for Environment (FOEN).

Accordingly, priority is given to the provision of flood protection measures for the settlements of Stans, Stansstad, Ennetbürgen and Buochs between the village of Dallenwil and the lake, some 8km downstream. However, whilst important infrastructure is protected using conventional structural methods, the flooding of farmland on the floodplain is considered to be tolerable. The key element of the protection scheme implemented on the Engelberg Aa River is the controlled flooding of selected areas. At high flows floodwaters can overtop flood banks at three locations and inundate farmland towards Lake Lucerne, without causing any damage to buildings or settlements. Other remaining risks are minimised through appropriate spatial planning measures which prohibit future building on the flood corridor. Additionally property owners have been provided with advice on the adoption of on-site measures to protect against residual flood risks.

77 In addition to the controlled overtopping of banks, some existing flood banks have been renovated and strengthened using with modern geotechnical techniques. The channel of the Engelberg Aa River has also been widening in order to improve not only the discharge capacity but also the structural diversity, and hence the ecology, of the river. To achieve this necessitated undertaking modifications to seven bridges. A final consideration is the restoration of the longitudinal connectivity in order to allow lake trout to once again be able to reach their spawning grounds.

78 The effectiveness of the CHF 26 million invested in the flood protection scheme was tested during flooding in 2005. It is estimated that investment was well made with some CHF 100 million worth of damage being avoided. Therefore the Swiss approach demonstrates that through restoring the connectivity between the river channel and the floodplain both economic and wider ecosystem benefits can accrue.

2.3.5 The Upper Mississippi, USA

79 The Mississippi River is the largest river system in North America. Along considerable lengths of the river much of the floodplain has been protected by a series of levees. However, a significant flood event, the 'Great Flood', in 1993 resulted in catastrophic damages throughout much of the Upper Mississippi River basin. Forty seven deaths were attributed to the flood and flood damages exceeded $15 billion. About half of the flood damages were related to agricultural losses. Approximately 74,000 people were evacuated and flooding damaged 72,000 homes.

80 Despite the fact that structural interventions, including levees, built by the United States Army Corps of Engineers (USACE) managed to prevent an estimated $19 billion in potential additional damages it was widely acknowledged that an integrated system of flood damage reduction and floodplain management measures could have further reduced the amount of damages incurred.

81 The US Congress provided the initial appropriation for the USACE to produce an Upper Mississippi River Comprehensive Plan (UMRCP) in 2002. This report was to assess flood management options by considering the functioning of the river system at a basin scale. A draft report was distributed for public review in May 2006; public meetings were held in June 2006; and substantial public input and comments were received and addressed. The final report was submitted to Congress in January 2009 (USACE, 2008).

82 The Comprehensive Plan for the Upper Mississippi and Illinois Rivers aimed to develop a systemic, integrated strategy and implementation plan for flood damage reduction and related environmental restoration. The UMRCP was developed in coordination with the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin; the Upper Mississippi River Basin Association; and non- governmental organizations such as the Upper Mississippi, Illinois, and Missouri Rivers Association, and the Mississippi River Basin Alliance. The work included documentation of the existing conditions, formulation and evaluation of alternatives for flood damage reduction, and public involvement efforts.

83 The UMRCP evaluated alternatives for a systemic, multipurpose flood damage reduction project that was consistent with environmental sustainability goals. Both structural and non-structural measures, including reconnecting the river with the floodplain, were considered in the development of options within the plan. The objectives developed from considering the problems, opportunities, and the authorizing language include:

- minimize the threat to health and safety resulting from flooding by using structural and non-structural flood damage reduction measures;
- reduce damages and costs associated with flooding;
- identify opportunities to support environmental sustainability/restoration goals of the Upper Mississippi and Illinois River floodplains as part of any systemic flood damage reduction plan;
- seek opportunities to address, in concert with flood damage reduction measures, other floodplain specific problems, needs and opportunities to include:
  - continued maintenance of the navigation project and related commercial infrastructure;
  - reduction of nutrient input and sedimentation into the rivers;
  - improved habitat management;
  - bank caving and erosion reduction;
  - improved recreation opportunities; and
  - identify and recommend appropriate follow-on studies.

84 Under the study, the Corps investigated a range of flood risk management options, ranging from do nothing to flood buyouts and non-structural plans, to structural alternatives with varying levels of protection. The study considered the benefits, risks and costs of every option. The evaluation of the alternative plans was accomplished using standard USACE procedures and included:

- The National Economic Development (NED) account which displayed changes in the economic value of the national output of goods and services;
- The Environmental Quality (EQ) account which displayed non-monetary effects on ecological, cultural, and aesthetic resources including the positive and adverse effects of ecosystem restoration plans;
- The Regional Economic Development (RED) account which displayed changes in the distribution of regional economic activity (e.g., income and employment); and
- The Other Social Effects (OSE) account which considered plan effects on social aspects such as community impacts, health and safety, displacement, energy conservation, and others.

85 None of the options considered was deemed to be economically feasible under the NED, because the costs outweighed the benefits, consequently the USACE could not recommend a plan to Congress. One of the options, known as **'Plan H'**, whilst not economically feasible when evaluated by NED guidelines, was identified as the best performing plan of those alternative plans evaluated.

86 **Plan H** proposed protecting areas with existing levees/floodwalls to the 0.2 percent chance annual (1 in 500-year) level of protection. The same level of protection was also applied to urban, agriculture and unprotected communities. It was proposed that the hydraulic impacts of this alternative on the Lower Mississippi River would be minimized through creation of additional storage areas and/or the exclusion of some agricultural districts from the plan. However, this plan also proposed that for areas where the cost of the levee improvement exceeded the value of the land to be protected that then no action should be taken.

87 By the end of 2010 Congress had yet to make a decision on the implementation of Plan H. Public consultation was on-going and follow-on studies were being developed. Several organisations have questioned the approach adopted by the USACE. An independent study conducted in 2004 (Hey et al., 2004) advocated an ecological solution to the flooding in the Upper Mississippi basin. Whilst not dismissing the use of levees as flood control devices, the study recommended a more aggressive floodplain restoration strategy which could convert almost 3 million hectares of cropland within the 1-in-100 year flood zone to active flood storage areas. The total net social benefit of this conversion was estimated to be $494 million. However, the study also recognised that further economic analysis of the benefits to both individual landowners and wider society was required. A further understanding of these benefits, such as value of restored wetlands for recreation or even for carbon credits, would have also been beneficial to the decision-making process within the UMRCP.

2.3.6 River Elbe, Germany

88 In 2002 parts of Germany experienced disastrous flooding in the River Elbe region with 21 people losing their lives and direct damage to property estimated at approximately €10 billion (Monstadt, 2008). The 2002 flood event led to intense public discussion on the inadequacies of the existing flood management strategies, the limitations of technical fixes and the negative effects of canalisation of the river. Immediately after the flooding, and partly driven by immediacy of an impending election, the Federal government developed a five point programme proclaiming a policy change towards a more precautionary approach to flood management. Consequently planned construction measures on the River Elbe were suspended. Based on the programme the Federal government developed and passed a Flood Control Act in May 2005. In addition to this the government announced the funding approval for a large protected area in Lenzen.

89 The conservation and restoration of the water retaining capacity of the floodplain had been established as a principle within the action plan for the Elbe in the late 1990s by the International Commission for the Protection of the Elbe. However, the magnitude of the 2002 floods catalysed a policy shift away from the traditional approach of building dams and dikes to one that gave the river more space and which sought to retain precipitation across the wider river basin.

90 The main physical intervention resulting in relocating 7.4km of dike up to a maximum 1.3km away from the river channel, and subsequently recreating 420ha of functional floodplain in the area of Lenzen. This work was completed in October 2008.

91 One of the key reasons for the success of this project was that the pre-conditions were relatively favourable. The area had an integrated regional administration responsible for nature conservation, flood protection and agriculture, a proactive and supportive farmer owning and cultivating much of the floodplain area and a sparsely populated area which already included protected areas. Key drivers which facilitated delivery within this enabling environment included: *(1)* the constant personal commitment of regional actors and their ability to interact in a cooperative manner which facilitated an open exchange of ideas, the re-allocation of property rights, the recognition of economic benefits and establishment of 'soft' tourism opportunities; and *(2)* the growing public acceptance of a new approach and the recognition that climate change brought with it uncertainties which required a novel approach to the management of flood risk.

92 Despite these positive drivers the project also had to address a range of constraints. Whilst there was some initial lack of acceptance of the concept, the implementation of a dedicated public awareness and promotional campaign, complemented by the personal commitment of the major landowner, minimised the local concerns. Despite the ever increasing public acceptance of the project, the planning process was prolonged, primarily due to the high level of innovation it embraced. The lack of analogies and knowledge of such schemes necessitated the development of several research activities in order to fill information gaps and practical experience.

93 The funding mechanisms had to deal with complex and sophisticated requirements including co-financing from numerous public and private organisations and sponsors. As part of this project managers had to negotiate compromises between multiple interests and requests. Furthermore, project management not only had to deal with convincing sponsors it also had to co-ordinate the interests of several policy sectors and private stakeholders. Spatial planning, nature conservation, flood protection and agricultural policies as well as the local policies of three neighbouring municipalities, environment groups and other relevant stakeholders all had to be considered. All of this caused a considerable strain on the various agencies involved.

94 Whilst the restoration of a considerable floodplain area has delivered significant benefits the ability to deliver a truly catchment-oriented approach to floodplain restoration has been limited. Aside from the project at Lenzen only a limited number of other floodplain areas have been restored and all have been delivered on a site by site basis. Consequently, ecological synergies and the development of an integrated and resilient network of restored floodplain areas have not been delivered. A stark example of this lies on the opposite bank of the Elbe at Lenzen. The river forms the border between Brandenburg and Lower Saxony, but despite good cross-border relations the floodplain restoration and flood management measures have yet to be extended to the Lower Saxony side of the river.

2.3.7 Key findings

95 The recommendations made in the Canadian and Swiss examples are reflected in the Integrated Flood Management (IFM) approach advocated by the World Meteorological Organisation,

which forms an integral component of Integrated Water Resource Management **(IWRM)** (WMO, 2009a). IFM recommends that the whole basin should be considered as the unit ecosystem and that economic effects should be addressed at a similar scale. Key to IFM is the principle embedded in the application of the ecosystem approach that environmental sustainability of flood management options is a fundamental prerequisite. Whilst this is not always practicable, it should remain the aspirational preference.

96 The rivers Skerne, Elbe and the larger Rhine Delta initiatives demonstrate that through the involvement of local communities and wider stakeholders it is possible to derive and implement sustainable solutions to flood risk management options. The Elbe example also highlights the importance of local advocates and the need for raising public understanding and awareness. However, the examples of the River Elbe and the Upper Mississippi also demonstrate some of the practical and political issues involved in trying to adopt an integrated approach across a river basin where cost- benefit analysis struggles to embrace ecosystem services in traditional economic decision-making. Often established economic tools, such as NED, fail to integrate fully the range of ecosystem services delivered by floodplain restoration. This can be compounded by the practicalities involved in ensuring comprehensive stakeholder engagement across large river basins with complex administration boundaries and multiple interests.

97 A recent publication goes as far as to suggest that the traditional approach to flood management in the Upper Mississippi is fundamentally wrong (Freitag et al., 2009). Given the uncertainties regarding rainfall patterns, with estimates that St. Louis may experience a 21 percent increase in precipitation within the next 30 years, it is important that flood management solutions focus on robust and sustainable flood risk prevention rather than on disaster relief. To achieve this it is essential that the multiple benefits associated with the restoration of floodplains are understood. This understanding needs to extend to all sectors of society from landowners, businesses and government agencies. Economists have demonstrated that society is still more focussed on disaster relief rather than disaster prevention with voters more likely to reward government office holders who provide finances for disaster relief, but not those who invest in disaster prevention (Healy and Malhotra, 2009). According to this study, a dollar spent on preventing flooding is more than ten times more valuable than a dollar spent on relief. Therefore the approach to sustainable flood management must acknowledge these financial lessons, and ensure that future flood management strategies are both cost-effective and environmentally robust and that the raising of awareness and education of stakeholders of the range of potential benefits is a fundamental element within this process.

2.4 Evaluation of ecosystem services

2.4.1 Barriers to embedding ecosystem services in flood management projects

98 The brief review of examples of floodplain restoration and flood management has demonstrated that an understanding of how to identify and balance trade-offs among different ecosystem services is essential if sustainable solutions are to be pursued. Economic analysis is often used to quantify these trade-offs, but, as the Upper Mississippi study demonstrates, economic analysis is not perfect. A principal reason for the decline of ecosystem services and their failure to be considered more fully in flood risk prevention is because consideration of their true values can be problematic in economic decision making. Most decisions are based on market prices,

but for many ecosystem services no markets exist, and decision makers have no clear signal for the value of the services. Understanding the true social value of non-marketed ecosystem services depends on the ways that services are used by different stakeholders.

99 A study conducted across Europe tried to understand the barriers to integrating 'soft' engineering approaches which deliver on range of ecosystem services within flood defence schemes (WWF, 2003). Whilst there is some evidence that in Europe there is a slow shift towards sustainable flood management principles there is still significant room for improvement, especially if stakeholders are to benefit from multiple ecosystem services. For instance, of the 15 countries surveyed less than 50% mentioned the restoration of abandoned or active meanders as flood defence measures. On a more positive note, 60% of the countries recognised the protection and restoration of floodplains as a means of storing flood water as an appropriate measure within national flood defence plans. The key barriers identified were: *(1)* the poor integration of soft-engineering measures into sectoral policies, for instance across departments with responsibility for nature conservation, urban planning, agriculture and transport; *(2)* poor involvement of the public, with just over a quarter of all countries surveyed involving non-governmental stakeholders in the development of flood management measures; and *(3)* lack of an assessment of the effectiveness of existing measures.

100 Therefore to better integrate ecosystem services into the decision-making process for flood risk management the following elements should be considered:

– Identification of possible ecosystem services;
– Stakeholder involvement in understanding of ecosystem services and defining trade-offs;
– Cross-sectoral recognition of the ecosystem services;
– Economic analysis of ecosystem services and the understanding of trade-offs; and
– Post project evaluation and assessment of the effectiveness of delivering multiple ecosystem services.

2.4.2 Approaches to identifying multiple objectives through ecosystem services

101 The importance of understanding which benefits floodplains and riverine wetlands deliver to society is not new. Whilst the MA standardised the nomenclature around ecosystem services, the desire to understand and assess these benefits spans several decades. Work undertaken in the United States in the 1980s pioneered rapid assessment approaches for the assessment of wetland functions and values (the pre-MA language for ecosystem services as described in **Section 2.1.2**) (Adamus, 1983; Larson et al., 1989). These early approaches considered a 'wetland', be it a floodplain wetland, as a homogeneous entity and provided simple ratings of wetland functions.

102 In the 1990s, as a response to the earlier methodologies, new approaches were developed based on understanding the hydrogeomorphology (HGM) of a wetland (Smith et al., 1995; Brinson et al., 1995). The approaches developed in the United States were driven by legislative requirements, such as the US Federal Clean Water Act. A parallel HGM-based initiative was also developed in Europe which, whilst working closely with American researchers, sought to produce a robust, science-based tool appropriate to assess the ecological, hydrological and biogeochemical functioning of European wetlands (Maltby et al., 1996).

103 The European functional assessment approach also developed associated valuation tools which integrating the understanding of the functions provided by wetlands with a socio-economic evaluation (Turner et al., 2000). This work has progressed since the turn of the century and complex decision- support systems are now available to assess the various ecosystem services provided by wetlands. The use of wetland functional assessment to assist in identifying ecosystem services in the development of sustainable flood management strategies is discussed below.

104 As the findings of the MA have become more widely distributed other tools have been developed to integrate the identification and assessment of ecosystem services into decision-making. Some of these are relevant to developing integrated sustainable solutions and multiple benefits as part of flood management objectives. A selection of these tools and approaches are reviewed below.

2.4.3 Wetland functional assessment

105 A functional approach to wetland assessment is one that acknowledges that wetlands can perform 'work' at a variety of spatial scales that can result in benefits for society, now widely termed ecosystem services. The conceptual approach behind understanding wetland functions is provided in **Section 2.1.2** of this paper.

106 In the United States several methodologies have been developed which set out to assess the 'functions' performed by both natural and restored or created wetlands (Smith et al., 1995; Brinson et al., 1995; Bartoldus et al., 1994). These methodologies usually assess against a predefined set of functions (see **Box 4**). The HGM approaches depend on the identification and either direct or indirect measurement of model variables in order to determine an index for the level of functioning (termed *Index of Functioning* or *Functional Capacity*). Usually the Index of Functioning relates to a reference standard which represents the highest level of sustainable functioning in the landscape.

107 A similar set of functional assessment procedures have been developed for European wetlands (Maltby, 2009). These procedures evaluate which functions a wetland is likely to perform based on the identification of key elements or predictors, which can be related to functions without the need for detailed empirical studies. The actual benefit society may or may not derive from these can then be assessed against a local or wider context.

108 Within the context of implementing floodplain restoration as a component of sustainable flood management, both the US and the European functional assessment approaches can be used to identify which functions, or ecosystem services, are currently being performed by a floodplain or riverine wetland and they can also be used to evaluate 'what if' scenarios. The use of indicators and predictors, whilst potentially data intensive, obviates the need to undertake extensive empirical studies.

109 For instance, the European functional assessment procedures could be used to assess whether a floodplain is currently improving river water quality through the storage of nutrients in organic matter or whether there would be an increase in this regulating service if flood banks were removed and inundation frequency and duration were increased as part of a flood management strategy. The functional assessment procedures define and assist in identifying controlling variables which need to be taken into consideration. In the case of storing nutrients

in organic matter on the floodplain the controlling variables are: nutrient input; organic matter status of the soil; soil water regime; vegetation type; and landform.

Box 4 — Functions of Riverine Wetland Classes Listed by Four Major Categories

1 Hydrologic
- Dynamic Surface Water Storage
- Long-Term Surface Water Storage
- Energy Dissipation
- Subsurface Storage of Water
- Moderation of Groundwater Flow or Discharge

2 Biogeochemical
- Nutrient Cycling
- Removal of Imported Elements and Compounds
- Retention of Particulates
- Organic Carbon Export

3 Plant Habitat
- Maintain Characteristic Plant Communities
- Maintain Characteristic Detrital Biomass

4 Animal Habitat
- Maintain Spatial Structure of Habitat
- Maintain Interspersion and Connectivity
- Maintain Distribution and Abundance of Invertebrates
- Maintain Distribution and Abundance of Vertebrates

110 The user of the functional assessment procedures has to conduct a desk study and a field study to gather appropriate information on the environment and the particular controlling variables relating to individual processes and, consequently, functions. This effectively generates a wetland database upon which assessments can be based. The European functional assessment procedures recognise that a wetland, or a floodplain area, may not be homogeneous and provide guidance on how to identify and delineate discrete landscape units based on differences in hydrogeomorphology. The subsequent assessment has two main steps: determination of the occurrence and performance of relevant processes which comprise each function; and, where applicable, the combination of groups of process outputs to provide an estimate of functioning. A similar structure has been illustrated previously in **Figure 3**.

111 Assessment outcomes are reached through an interrogation of the wetland database via a series of questions and answer sheets. The European procedures have been translated into a CD-ROM format to facilitate easier data entry and to automatically generate outcomes. The approach also allows a user to assess across all functions or to select individual topics of interest.

112 Whilst potentially data intensive, functional assessment approaches provide useful tools for identifying and assessing wetland functions and consequently ecosystem services. Such assessment procedures could be utilised in an evaluation of the provision of actual and potential ecosystem services associated with floodplain restoration as a component of a sustainable flood strategy.

113 Such an approach is advocated in the 'Ecoflood Guidelines', produced on behalf of the European Commission, which promote the use of floodplains as natural flood defence measures whilst at the same time optimising other compatible functions and services (Blackwell and Maltby, 2005). One

of the key messages that the Ecoflood Guidelines expresses is that the rewetting of floodplain soils as part of a restoration project can play a significant role in the regulation of nutrients, heavy metals and other river borne contaminants and deliver catchment scale benefits to water quality.

2.4.4 IUCN Integrated wetland assessment toolkit

114 One of the acknowledged reasons behind the loss of wetlands, including the truncation of hydrological connectivity between a river and its floodplain through the creation of flood defence infrastructure and the draining of floodplains, is due to a lack of tools to facilitate informed and appropriate decision-making. Often management decisions are made in ignorance of the wider ecosystem services wetlands provide. Therefore both the costs of wetland loss and their potential to provide sustainable and multifunctional solutions are underestimated.

115 Against this background an integrated approach to wetland assessment has been developed by the IUCN (Springate-Baginski et al., 2009). Acknowledging that methodological and information gaps partly explain the omission of wetland ecosystem services and the value they possess from certain decision-making circles, the key barrier identified relates to the lack of a joined-up or integrated approach which assesses inter-linkage and connectivity between wetland condition and economic/livelihood status. Consequently the inability to express this information compromises the potential to inform and influence both nature conservation and development planning. This conclusion applies equally to the development of flood management strategies.

116 The IUCN toolkit (Springate-Baginski et al., 2009) sets out a process for integrated wetland assessment and provides methods to investigate the linkages between biodiversity, economics and livelihoods. The toolkit also allows potential conflicts of interest between nature conservation and inappropriate development to be identified and aims to strengthen pro-poor approaches to river and floodplain conservation.

117 The assessment approach sets out a process for determining and describing the status, characteristics, or worth of a particular wetland area. As with the functional assessment approaches, the toolkit involves identifying and measuring certain variables which are considered important in conservation or development terms, and can be taken as indicators of the health of the wetland itself, its attributes, functions and ecosystem services and of the livelihoods it supports. The approach aims to be fully integrated so that exchanges of ideas can take place at all stages in the process, from defining objectives, through carrying out field work, to analysis of data and the final reporting and presentation of outcomes. This generates a decision-making realm where rather than separate assessments being undertaken for biodiversity, economic and social issues, the decision-making process is integrated from start to finish. However, one of the recognised limitations of such an approach is that to complete a fully integrated assessment places significant demands on the time and effort to plan, conceptualise and undertake the process.

118 **Figure 5** demonstrates the integrated construct. Joined up objectives and research questions are defined prior to data collection. The field survey element involve defining the spatial and temporal boundaries of the area under assessment, gathering information on the physical environment and the biodiversity it supports, and linking this information with the values that stakeholders derive from the ecosystem. Understanding the value of the services provided can

be problematic and a variety of methods are advocated in order to capture both the obvious values, such as for the value of timber which may be sold for export, therefore possessing a clear market value, and the hidden values, such as the ability of a wetland area to remove pollutants and supply clean drinking water.

119 To understand the range of ecosystem services and, where possible, to monetarise their economic value can be a complex exercise. The toolkit approach recommends identifying the component species or resources and developing understanding of their importance through interviews, household surveys, workshops and a range of appropriate fora in order to engage fully with stakeholders. Whilst potentially time-consuming this approach provides a strong and integrated link between the biodiversity and ecosystem processes and services, and their subsequent value, provided by a wetland area.

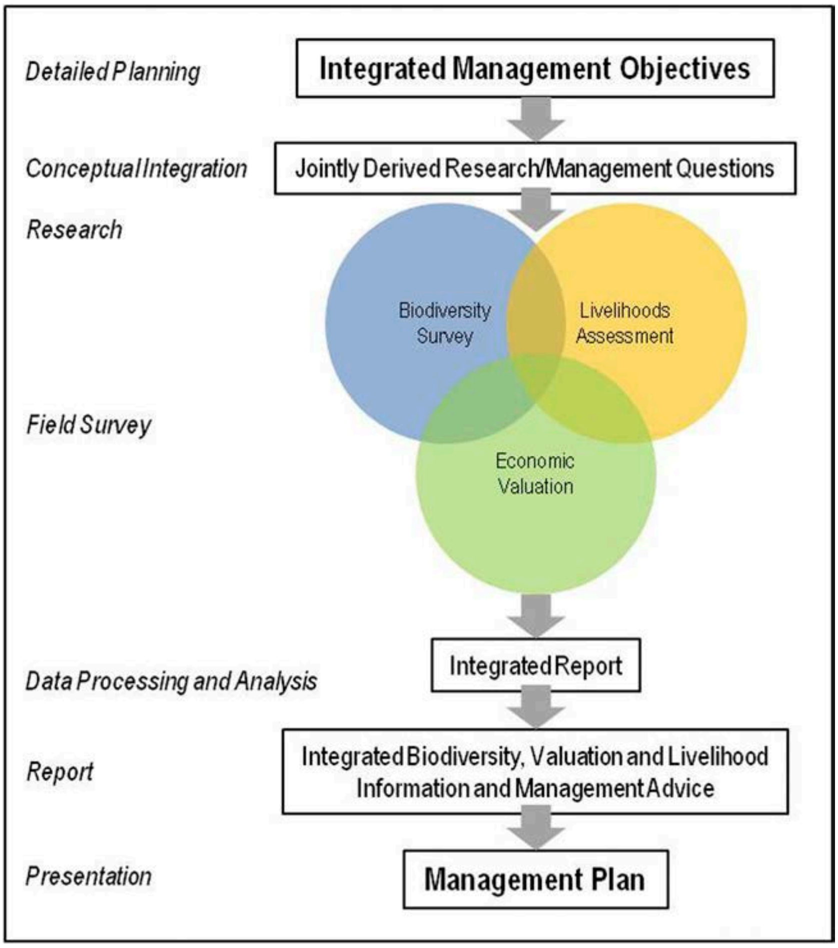

Figure 5 — Integrated wetland assessment procedure (based on *Springate-Baginski et al., 2009*).

120 One of the key approaches recommended is to establish a list of ecosystem services (such as the one displayed in **Box 3**) and ask stakeholders to rank them by perceived relative importance. This approach can be extended to assess the geographic reach of the service as local, national, regional or global. Once identified, it is possible to place economic values on the ecosystem services. However, it should be noted that however academically interesting it may be to know the monetary value of a particular service, valuation is not the end in itself. It is a means to an end, in that it should be used to facilitate better informed decision-making.

121 The valuation of services needs to be set in the spatial and geographic context of the study area. Rarely should it be necessary to consider every service and its value to every stakeholder. The scope of any valuation needs to be set against the overall context of the project under consideration.

122 A variety of techniques are available for deriving the economic value of a wetland. These take several forms including direct values (where markets exist), option values, indirect values, existence values, management costs and opportunity costs. The Integrated Toolkit reviews the various techniques and summarises the primary and secondary data collection sources required to complete an economic evaluation and explains how to integrate this with an understanding of livelihoods and biodiversity conservation objectives.

123 Substantial elements of the Integrated Toolkit have resonance for understanding the importance of allowing floodplains to flood and for the restoration of degraded rivers and floodplains. The linkage between biodiversity benefits, economic valuation and livelihood support represents a key strength of the approach and is particularly relevant in areas of the world where society's direct dependence on wetlands to maintain their well-being is strongest.

2.4.5 WRI ecosystem services: a guide for decision-makers

124 The World Resources Institute (WRI) has developed several publications which aim to mainstream ecosystem services into public and private decision-making (Ranganathan et al., 2008). Recognising that information on ecosystem services can strengthen a variety of decision-making processes, including flood management strategies, the WRI has produced an approach to enable decision-makers to focus on those services most likely to be of risk or opportunity to a specific project or plan. This process embraces five key steps which entail collecting information on various elements of ecosystem services and moving progressively towards and understanding of ecosystem service- related risks and opportunities associated with a decision or plan **(Figure 6)**.

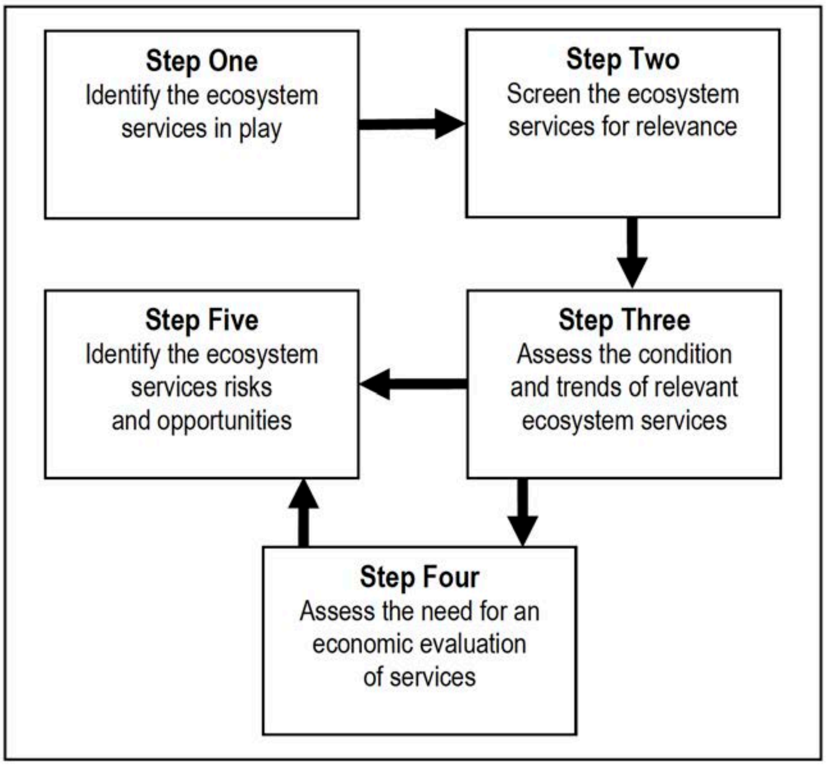

Figure 6 — Overview of steps in assessing risks and opportunities related to ecosystem services (based on *Ranganathan et al., 2008)*.

125 The first step involves a systematic consideration of all ecosystem services and whether the proposed project or decision has an impact. Although some linkages may seem obvious, for instance the flooding of cropland on as a result of realigning flood embankments will impact on food production, a systematic dependency analysis increases the likelihood of revealing unforeseen impacts, which may be positive or negative, or dependencies. Identifying these at the beginning of a process facilitates subsequent management of risks and opportunities.

126 The approach recommends starting with a list of ecosystem services (such as the one presented in **Box 3**) and to systematically consider whether the proposed action, such as the restoration of a floodplain to store flood waters, depends on or affects each service. This consideration needs to take into account both direct and indirect affects and should expand to a landscape or a river basin scale to ensure that spatial and temporal considerations are addressed.

127 In a simplified example, evaluating two flood management option may require an assessment of the trade-offs between building a new flood embankment or allowing a floodplain to be inundated by breaching an existing flood bank. Building a new flood bank may require the quarrying of material in the uplands of a river basin. The quarrying activity may require forest clearance and may also alter the hydrogeological regime in the area and compromise local springs. The removal of an existing flood bank may reduce the productivity of formerly protected agricultural land but equally it may facilitate the deposition of nitrogen and phosphorus improving water quality further downstream in the catchment. The trade-offs over time and across space between these options may have been missed if the geographic focus is too narrow or the time horizon too short.

128 The second step entails screening the identified ecosystem services to determine which are most relevant to the project and require further consideration. Often finite resources will limit the detail to which an assessment can be made therefore this step assists in prioritising resources. The dependence of a decision on a particular ecosystem service is most likely to be relevant where no cost-effective substitute exists for the service. For instance a substitute may include a manufactured alternative, such as the establishment of a water treatment plant to replace the natural water quality attenuation function of a floodplain wetland or the creation of built sea wall to replace lost coastal mangroves. However, the existence of an alternative is not sufficient; it has to be cost-effective relative to the ecosystem service it replaces.

129 A key consideration in determining whether a project or plan will generate a relevant impact on an ecosystem service is whether the ability of other users or beneficiaries of the service are affected. To fully assess this requires a comprehensive understanding of the appropriate spatial and temporal scales. Key questions to be considered in this process include:

- Is the decision's impact a large share of the total local or regional impact?
- Is the ecosystem service in short supply relative to demand?
- Could the decision's impact push the ecosystem service across a biological threshold that leads to a scarcity of the service?

130 In this process it is important to understand that different beneficiaries may have different responses and different levels of understanding. For instance, indigenous people may place a higher importance on the cultural services provided by sacred places or species. Additionally, the impacts on many services can go relatively unnoticed until the cumulative impact over time pushes beyond an ecological threshold. An example of this is the case of macrophyte dominated clear water lakes which, following a gradual accumulation of nutrients, can switch in a very short time to turbid, algal dominated systems. In cases of uncertainty it is recommended to err on the side of conservatism and include the service in the detailed assessment in step three.

131 Step three of the process demands a more detailed assessment of the ecosystem services. This assessment should focus on answering the following three questions:

- What are the condition and trends of the selected ecosystem services?
- What are the major drivers affecting the ecosystem services?
- What thresholds or irreversible changes have been observed in the ecosystem services?

132 Whilst these questions are important the process should remain flexible and allow for medications or expansion depending on the feedback from stakeholders. During this step there are a range of issues to consider associated with the gathering and processing of data. These include ensuring that essential participatory assessments remain affordable, that the boundaries of the assessment are understood and set at the appropriate scale, making sure that information gaps are plugged through the necessary collection of empirical data, and taking uncertainties into account.

133 Often data deficiencies are implicated as a barrier to conducting an assessment of ecosystem services. However even with shortcomings in data availability and pedigree some form of assessment should be possible. Often indicators or surrogates can be used to measure

ecosystem services, especially for those were direct measurement is problematic. For instance, the nutrient concentrations in river water could be used as a surrogate for the water purification role of wetlands within a catchment. Consultation with experts and stakeholders can be an efficient way of determining appropriate indicators of ecosystem services and can provide meaningful and measurable results.

134 Understanding the current direct and indirect drivers of change affecting ecosystem services is essential in order to establish a baseline against which any proposal can be assessed. Individual drivers of change should be mapped against individual ecosystem services and then reassessed in relation to the proposals.

135 When considering drivers of change and the subsequent affect on ecosystem services it is worth noting that environmental changes and their associated responses are not necessarily linear or predictable. Ecosystem services may be party to natural and periodical cycles of collapse and renewal, as has been observed in fish stock collapses. An assessment of ecosystem services should aim to predict how disruptions can be managed to ensure that ecosystems and society remain resilient to changes and impacts.

136 Economic valuation attempts to monetarise in a universal currency the value of an ecosystem service. A key strength in this approach is that by assigning a monetary value it is possible to draw attention to an ecosystem service which may otherwise have been ignored or excluded from a decision-making process. Within this process a decision-maker needs to determine whether an economic evaluation is required, therefore this step is optional. In some cases the impacts on human health or well-being may form a more important focus for finite resources.

137 As with previous techniques, the WRI approach advocates a range of methods to quantify the values associated with ecosystem services including direct use, indirect use and non-use values. The approach also recognises that there can be limitations with economic evaluation with the results often being highly subjective and sensitive to the methods selected and the assumptions applied. There can also be suspicion of economic values. Therefore, it is recommended that in developing economic values all analytical techniques and methods are presented in a transparent form so that ambiguities or perceived discrepancies are visible and open to discussion and scrutiny.

138 Step five involves using the information accumulated in the previous steps to assess the risks and opportunities associated with the planned project or decision. Risks and opportunities can relate to both the dependence of the project's goals on ecosystem services and how the decision affects services that stakeholders depend on. The following questions should be considered when identifying risks and opportunities associated with ecosystem service dependencies and impacts:

- Does the project or proposal depend on ecosystem services that were previously unknown or in poorer condition than previously acknowledged?
- Could the overall objectives of the plan be compromised because stakeholders are competing for ecosystem services which are in limited supply?
- If this is the case, are there other cost effective substitutes available?
- Are there any unforeseen impacts of the project on ecosystem services that other stakeholders depend on for their well-being?

139 The WRI approach also recommends considering trade-offs among ecosystem services when assessing risks and opportunities. Such an assessment will allow different groups that either win or lose in either the short or long term as a result of a decision to alter an ecosystem service.

140 Several of the elements of the WRI approach are also embraced by the previous methods for understanding and assessing ecosystem services. The approach allows not only the current status ecosystem services to be understood but also addresses potential risks and opportunities to be understood to facilitate a comprehensive understanding to be achieved.

2.4.6 The Economics of Ecosystems and Biodiversity

141 The Economics of Ecosystems and Biodiversity (TEEB) study represents a major international initiative to draw attention to the global economic benefits of biodiversity, to highlight the growing costs of biodiversity loss and ecosystem degradation, and to draw together expertise from the fields of science, economics and policy to enable practical actions moving forward (TEEB, 2010a).

142 As with other studies, TEEB does not advocate valuation as a panacea, but rather as a tool to make the value of biodiversity visible and to prevent the inefficient use or even destruction of the natural capital that is the foundation of our global economies. Various approaches to understanding the economic importance of biodiversity and the ecosystem services it supports have been developed by TEEB including guidance for local and regional policy makers and businesses.

143 The TEEB approach adopts a tiered structure with the valuation of biodiversity and ecosystem services being implemented in a more or less explicit manner according to the situation under consideration. It is recognised that for every decision or plan the context can be different; hence the approach does not recommend a single valuation process that can be prescribed for every situation. However, a broad framework is proposed that can be useful as a first step towards bringing the value of biodiversity into mainstream economic decision-making. This approach can be adapted to fit individual needs and circumstances, based on the three following steps.

144 The first step is to identify and assess the full range of ecosystem services affected by a project or plan and to consider the implications for different groups in society. This step requires the consideration and involvement of the full range of stakeholders influencing and/or benefiting from the affected ecosystem services and biodiversity. Under some circumstances the evaluation process can be terminated here without progressing to a monetarisation of ecosystem services.

145 The second step aims to estimate and demonstrate the value of ecosystem services, using appropriate methods. Analysis needs to examine the linkages over scale and time that affect when and where the costs and benefits of particular uses of biodiversity and ecosystem services are realized to help frame the distributive impacts of decisions (for instance from local to global contexts, current use versus future resilience, upstream to downstream and urban to rural).

146 The final step involves capturing the value of ecosystem services and seeking solutions to overcome their undervaluation. This usual involves using economically informed policy instruments. Tools may include changes in subsidies and fiscal incentives, charging for access and use, payments for ecosystem services, targeting biodiversity in poverty reduction and climate adaptation/mitigation strategies, creation and strengthening of property rights and liability, voluntary eco-labelling and certification. The choice of tools will depend on context and take into account the costs of implementation. Practical guidance and illustrations of these steps are provided in the TEEB reports (TEEB, 2010a), and are supported by a collection of case studies from the local and regional level which are available online (TEEB, 2010b). Anyone following the TEEB approach is encouraged to navigate through the various resources to find aspects of the approach most relevant to the situation under consideration.

2.4.7 Payments for Ecosystem Services (PES)

147 In November 2006 the Parties to the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) adopted as an innovative policy instrument the Recommendations on Payments for Ecosystem Services in Integrated Water Resources Management (UNECE, 2006). These Recommendations indicate the measures to apply in order to integrate into sustainable development policies the value of services supplied by water-related ecosystems – such as forests and wetlands – as well as the measures to provide compensation for such services. Thus, objective of the Recommendations is to improve the overall framework for the protection, restoration and sustainable use of ecosystems and their services, through innovative financing mechanisms – and more specifically payments for ecosystem services (PES) – which have become crucial in recent years for addressing failures in environmental management.

148 Through PES it is possible to internalize in decision making environmental costs and benefits. When financial resources to address serious environmental concerns are limited, PES can generate additional resources, redirect funds to environmentally friendly technologies and sustainable production patterns, create incentives for investment, and increase private-sector involvement in environmental protection. PES have the potential to improve the quality of decision-making and facilitate the integration at all levels of relevant policies (e.g. agriculture and forestry, urban development, water, energy and transport), and therefore also flood management.

149 Experience has shown, however, that PES can contribute to more sustainable management of resources only if specific conditions are met. Therefore, the UNECE Recommendations are based on good practices and lessons learned in the implementation of PES, providing step-by-step guidance for their design and implementation: from how to determine whether ecosystems can provide the necessary services to solve existing water management issues, to how to value such services in order to make informed decisions and optimal choices, and how to balance the requirements of economic efficiency with broader societal and equity objectives.

2.4.8 Other issues relating to assessing ecosystem services

150 Since the late 1990s the academic literature has abounded with discussions about ecosystem services and the various approaches to identifying, understanding and evaluating them. Some

of the literature has focussed on how the MA nomenclature mixes processes (means) for achieving ecosystem services with the services themselves (ends). For instance pollination, described in the MA classification as a regulating service (an end), is in fact a means to achieve food production (a means) (Wallace, 2007). However some researchers argue that any attempt at classifying ecosystem services should be based on both the characteristics of the ecosystems of interest and a decision-based context for which the concept of ecosystem services is being utilized (Fisher et al., 2009). This has lead some researchers to recommend that rather than getting hung up on the rights or wrongs of one system, we may need to accept that multiple classifications are required depending on the application (Costanza, 2008).

151 In addition to agreeing a finite or universally acceptable nomenclature or classification, there are still also relatively few examples of well-defined methodologies for identifying and quantifying services or for producing inventories of ecosystem services. Often there is a reliance on participatory approaches and intensive engagement with stakeholders. Whilst this can yield good results it can also be resource intensive. Some research has also argued that different stakeholders can generate different values.

152 A study conducted on coastal mangroves in Mexico demonstrated that focus groups and individual interviews do not reveal equal sets of information nor do they rank ecosystem services comparably (Kaplowitz, 2000). The results also demonstrate the difficulty of designing studies and instruments for estimating the total economic value of a complex ecosystem such as wetlands. Valuing non-market and non-use services associated with natural resources, especially in developing countries, seems to require extra care. This work highlights the importance of using multiple qualitative methods for identifying potential values of ecosystem systems. A similar study in Australia attempted to circumvent the issues relating to a dependence on purely local stakeholders and convened workshops which combined local knowledge with leading experts in several disciplines to assemble a list of products and values associated with a diverse catchment (Shelton et al., 2001). Pre- prepared lists of products and ecosystem services were utilised as prompts to facilitate the process.

153 The key message is that no process for assessing ecosystem services and consequently describing the multiple benefits associated with a proposed project is perfect. A range of issues, as discussed above, need to be considered and a bespoke solution needs to be evolved for each situation. However, by careful consideration of the both limitations and benefits of the approaches described above the tools exist to ensure that multiple objectives can be considered within floodplain restoration projects.

3 INTEGRATING ECOSYSTEM SERVICES AND FLOOD MANAGEMENT

3.1 Conceptual elements

3.1.1 Is it possible to serve multiple objectives?

154 In recent years a considerable volume of scientific literature has been generated proposing integrated strategies for the restoration of rivers and floodplains (Buijse et al., 2002; Woolsey et al., 2007; Moss, 2007; Rohde et al., 2006). Some of the literature has focussed on the need to restore floodplains as part of future flood risk strategies (Wheater and Evans, 2009; Wheater, 2006; Hey et al., 2009; McAllister et al., 2000) whilst a limited number of papers has proposed a multifunctional approach to river and floodplain restoration (Tockner and Stanford, 2002; Pahl-Wostl, 2006). Similarly there has been a profusion of literature on ecosystem services as demonstrated above.

155 Whilst there are many implicit linkages between these two bodies of scientific literature there are limited explicit synergies. However, there is a clear pathway which allows the objectives of, and approaches to, river and floodplain restoration, utilising the strategies and practical methods described in the examples provided, to be integrated with the evaluation and assessment of ecosystem services in order to deliver on multiple objectives as a component of flood management. The fundamental elements in trying to serve multiple objectives are firstly being aware of the possibilities and secondly understanding how trade-offs between possibilities can be managed in order to sustainably deliver a multiplicity of benefits to a multitude of beneficiaries. A review of wetland restoration project in England demonstrated that in all the case studies examined every project delivered both on planned ecosystem services as well as delivering a range of serendipitous ecosystem services (McInnes, 2007). With careful planning and greater awareness it is possible that the benefits could have been improved and better optimised.

156 Traditional 'structural' or 'engineering' solutions to flood risk management are increasingly being questioned, and arguably have been exposed, as the floods in recent years in Europe and the United States have highlighted only too tragically. Instead of providing protection, often modern large-scale dam and dike structures can result in an increase in the scale of damage, partly because people living in floodplains are prone to overestimate the level of protection provided, particularly when rainfall events exceed 100-year event (WWF, 2002).

157 Integrated Flood Management offers the opportunity to deliver a range of benefits to a variety of stakeholders. Traditional structural interventions have lead to a separation of the river from its floodplain and a subsequent erosion of ecological potential and ecosystem services. Soft engineering approaches which encourage the water to be stored on the floodplain, and where there is 'room for river, as in the case of the Rhine Delta, provide the potential to revitalise ecosystem services and 'reanimate' the landscape. Such approaches, as has been demonstrate on the River Elbe, can provide sustainable flood management and provide other benefits such as tourism and even allow agriculture, if under a different systems, to continue.

158 Therefore, it should be possible to serve multiple objectives without compromising levels of flood protection. To achieve this integration the following framework and process is recommended as way to consider multiple ecosystems services in future flood management strategies.

3.2 Proposed framework

3.2.1 How to serve multiple objectives

159 Worldwide, the number of river and floodplain restoration projects has increased exponentially over the past few years (Nakamura et al., 2006). Some of the examples discussed in this paper, such as the River Skerne in the UK or the River Elbe in Germany, have demonstrated that it is possible to deliver 'soft engineering' approaches to flood risk management, such as through re-meandering rivers or removing engineered flood banks, which not only attenuate flooding but also provide numerous other benefits. The case studies presented provide some important insights into the barriers and opportunities which need to be considered when developing plans to restore floodplains for flood management.

160 This review has also demonstrated that there are several methods and approaches to understanding and assessing ecosystem services. These techniques all vary slightly in their scope and purpose but all possess a level of utility which transfers directly to the development of sustainable flood risk management strategies. Whilst not always an historical priority, if multiple objectives are to be satisfied then a more comprehensive evaluation and integration of ecosystem services in combination with an inclusive consideration of 'soft engineering' techniques is required. This approach is compatible to the recommendation derived from a recent review in Japan that the main goal of restoration should be to link sustainable use of rivers and wetlands with human well-being (Nakamura et al., 2006).

161 Several authors have advocated strategies or approaches to floodplain or wetland restoration (Holl and Cairns, 1996; Van der Valk, 2009; Ramsar Convention Secretariat. 2007). Often general principles and guidelines have been based upon experience with many projects in many settings and they provide a synthesis of the underlying ideas that form the foundation of successful restoration

projects. For instance the Ramsar Convention has developed guidance on wetland restoration which is applicable within the context of restoring floodplains as part of a flood management strategy (Ramsar Convention Secretariat. 2007). However, it should be noted that every floodplain restoration project is potentially unique, and whilst generic principles and guidelines can be designed to be useful in many situations, they should not be considered to be universally applicable nor definitive. **Box 5** summarises the key issues for integration within such generic principles.

Box 5 — Issues to be integrated into a framework for the development of sustainable river and floodplain restoration in order to deliver on multiple objectives

Soft engineering approaches - The following approaches inter alia should be considered:

- Re-meandering of the main river channel
- Increasing the floodplain width
- Creating new or reconnecting old channels
- Removing artificial flood embankments
- Limiting or removing obstructions to flood flows

Catchment scale considerations - The following approaches inter alia should be considered:

- Understand catchment scale land use planning and management
- Ensure hydrological connectivity
- Consider both water quality and quantity issues

Institutional issues - The following issues need to be considered and addressed:

- Cross sectoral integration and joined-up thinking is essential
- Ensuring strong political will and backing
- Establishing local advocates
- Developing public awareness, acceptance and involvement

Participation - The involvement and participation of the following in situ and ex situ stakeholders is essential:

- Local stakeholders
- Wider stakeholders
- Experts

Integration of ecosystem services within the objectives:

- Objective setting should seek include multiple benefits or ecosystem services (see **Box 6**)

162 A variety of approaches exist which utilise 'soft engineering' rather than hard structural interventions. The examples discussed in this paper illustrate some of the techniques, such as re-meandering channels, removing flood banks or making 'room for the river'. Apart from biodiversity or nature conservation benefits, the utilisation of such techniques provides opportunities to integrate other benefits, such as aesthetics, recreation, education and water

quality improvement, into flood management projects. Whilst soft engineering approaches traditionally take river reach focus, some considerations should be extended to the catchment scale. Flood risk management, whilst often focussed on the floodplain as a high risk receptor, should start with understanding how catchment scale land use contributes to flood risk. Appropriate changes across a river basin in land use zoning, practice and management can generate the dual benefits of attenuating flooding and improving water quality.

163 To successfully deliver on multiple objectives often requires strong cross sectoral institutional structures. Government departments need to recognise their mutual contribution to flooding issues and their shared responsibilities in ensuring that solutions optimise the benefits across different sectors. Sustainable flood management provides benefits across normal institutional boundaries. For instance, the restoration of a floodplain area may provide health, transport, agricultural, tourism, water resource and recreational benefits. Differing governmental drivers should be considered to ensure a joined-up approach does not exclude opportunities and therefore compromise the delivery of ecosystem services. Often to achieve this requires strong advocates, both from within governments but also drawn from the wider society, to promote multiple interests across a range of fora.

164 Governments, NGOs and other interested parties need to promote the multiple opportunities provided by flood management. The need for greater application of communication, education, participation and public awareness (CEPA) extends both within and without government agencies, the private sector, NGOs and the general public. Demonstration projects can be hugely influential in explaining the benefits of restoring floodplains to a range of previously sceptic stakeholders. The River Quaggy at Sutcliffe Park in South London, England, is an excellent example of how a project can be used as a demonstration site to promote the multi-functional components of floodplain restoration.

165 The River Quaggy had previously been culverted under urban playing fields. Local residents became progressively more aware of the river as the frequency of flooding increased as development intensified across the local area. Instead of adopting a traditional engineering led approach to solving the problem, the Government body responsible for flood risk management, the Environment Agency (EA), decided to combine flood risk management with a strategy for river restoration that would benefit the local community (Environment Agency, 2006).

166 A new 'low-flow' meandering channel was created through the park, based on its original alignment. The historical culvert was retained, enabling it to take excess water during high flow events. Flow between the two watercourses is now regulated by a sluice. To provide further flood water storage, the park itself was lowered and re-landscaped to create a floodplain capable of storing a maximum of 85,000 cubic metres of water. A network of boardwalks, footpaths, viewing points and interpretation boards were designed to encourage access to the river and wetlands.

167 Apart from protecting 600 homes from flooding, improving biodiversity and the overall aesthetics of a degraded urban landscape the scheme has also generated significant improvements in human health. Before the restoration works, most people (42%) used the park to walk dogs. Following the improvements, the number of visits to the park increased by 73% and most visits were for exercise, increasing from 40% to 68%. A survey conducted by the University of Essex showed that people are more than twice as likely to visit for 'health' reasons (66%

compared to 25% previously) such as fresh air or walking since the river and floodplain have been restored (Peacock et al., 2005).

168 Examples such as the River Quaggy, set within a major urban centre, can act as strong messengers in the pursuit of raising awareness regarding the multiple benefits of floodplain restoration. Being able to take stakeholders to meet other local stakeholders and to understand better the possibilities and potential benefits aids greatly the CEPA process.

169 The role of engaging and participating fully with both in situ and ex situ stakeholders is essential not just to understand flood risk management but to also ensuring opportunities that benefit all sectors of society are not overlooked or ignored. This element is at the heart of ensuring that all ecosystem services that may be in play are considered fully. This involves understanding how they may operate, potentially through the application of some form of functional assessment, and how relevant they may be to the planned project. The key stages in understanding ecosystem services and their relevance to a proposed flood management project are set out in **Box 6**.

Box 6 — Sequential consideration of ecosystem services

Step 1: **Identification of ecosystem services**

- Use checklists to assess which ecosystem services are considered important.
- Employ participatory approaches to understand ecosystem services from a stakeholder perspective.
- Use a simple absence / presence checklist.
- Consider ranking ecosystem services in order of relative importance for stakeholders.

Step 2: **Quantification of ecosystem services**

- Use surrogates or indicators to quantify the importance of ecosystem services.
- Undertake a functitonal assessment to evaluate controls and to generate a numerical understanding.
- Conduct empirical studies to quantify ecosystem services.

Step 3: **Screen the ecosystem services for relevance**

- Understand the spatial and temporal limits to the ecosystem services.
- Understand which ecosystem services are relevant to the project and to which stakeholders.

Step 4: **Monetarise ecosystem services**

- Use the appropriate economic valuation technique to value ecosystem services.

Step 5: **Understand risks and opportunities**

- Evaluate the direct and indirect risks and opportunities associated with the project.
- Investigate trade-offs among ecosystem services.
- Revisit project objectives in light of understanding risks and opportunities.

170 It is possible to map onto existing strategies the key issues identified in this paper to provide a generic strategy, or framework, for river and floodplain restoration which provides the

opportunity to consider integrating ecosystem services to deliver on multiple objectives. A generic framework is shown in **Figure 7**. This adapts the guidelines for wetland restoration produced by the Ramsar Convention (Ramsar Convention Secretariat. 2007), and endorsed by 160 contracting parties, and integrates the step wise consideration of ecosystem services as presented in **Box 6**.

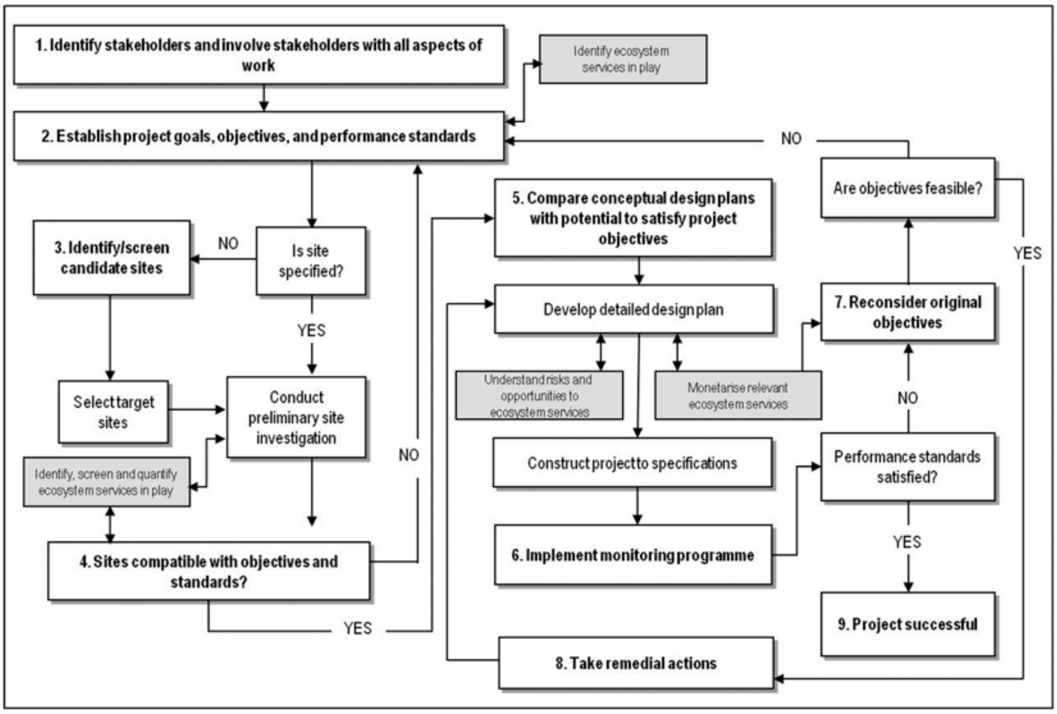

Figure 7 — Framework for integrating the consideration of ecosystem services with standardised river and floodplain restoration guidelines (modified from *Ramsar Convention Secretariat, 2007)*.

171 The framework presented in **Figure 7** is inherently generic. Situations may develop where the steps in the process deviate to a different path. For instance the economic valuation of ecosystem services may required at an earlier point in the process to facilitate cost-benefit analysis for site comparison purposes. It is not the precise timing of the consideration of the various steps described in **Box 6** which is important is the actual process of deliberating over the potential ecosystem services which is paramount if multiple objectives are to be both considered and delivered.

4 CONCLUSIONS

172 This paper demonstrates that innovation can work. Good examples of integrated and sustainable flood management do exist. Based on a critical assessment of the existing barriers key considerations have been produced. These range from utilising soft engineering approaches, to improving governmental cross-sectoral working, to considering catchment-scale solutions and ensuring the participation of a range of relevant stakeholders. Acting on these considerations will ensure greater sustainability of solutions. However, by acting on these whilst considering that every flood management problem is actually an opportunity to use natural processes and systems to deliver not just a reduced risk and susceptibility to flooding but a range of other benefits across a variety of stakeholders will provide a truly sustainable outcome.

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