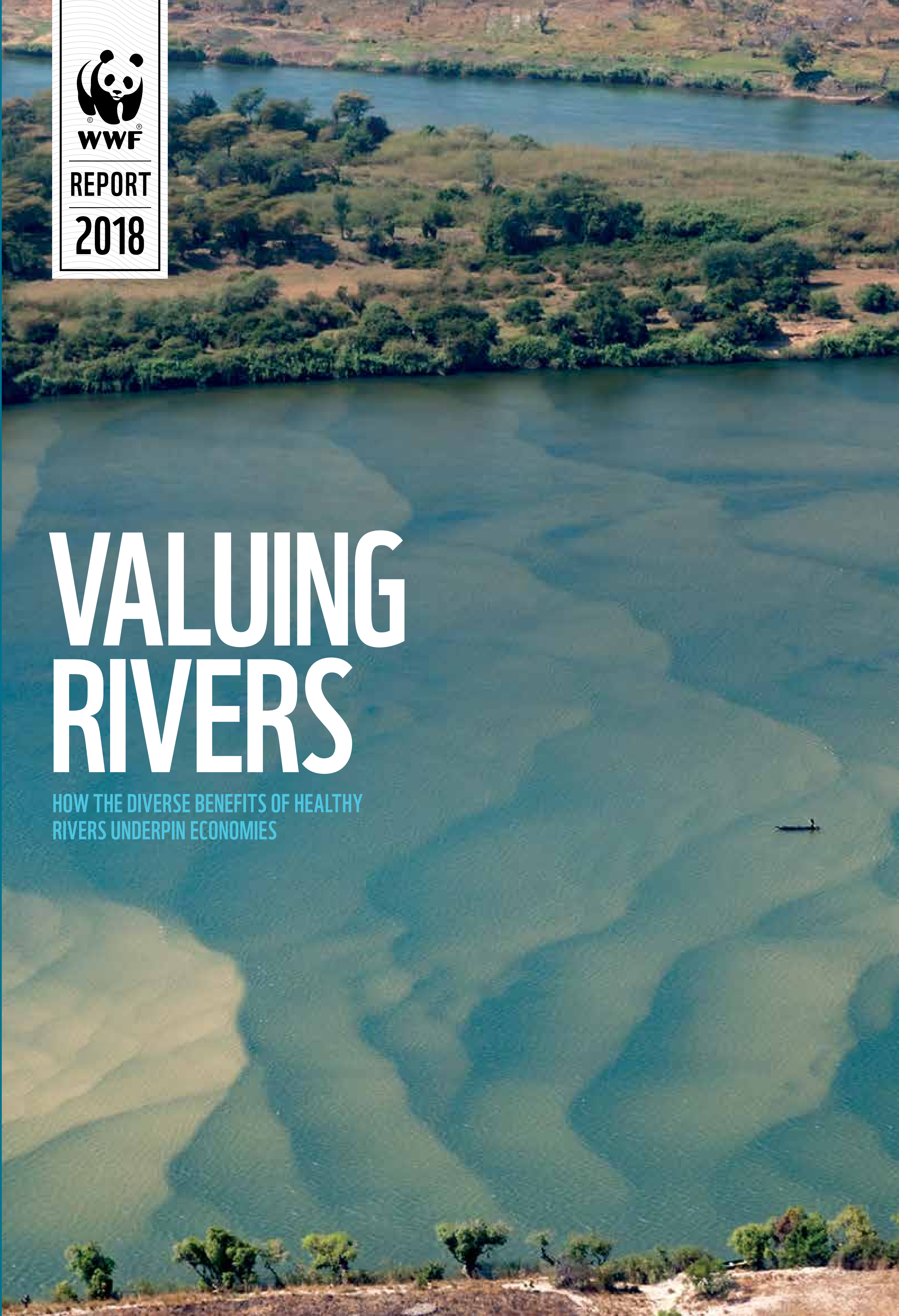

WWF

REPORT 2018

VALUING RIVERS

HOW THE DIVERSE BENEFITS OF HEALTHY RIVERS UNDERPIN ECONOMIES

Lead author: Jeff Opperman, WWF Global Science

Contributors: Stuart Orr (WWF-International), Hannah Baleta (WWF-Myanmar), Dustin Garrick (University of Oxford), Marc Goichot (WWF-Greater Mekong), Amy McCoy (University of Arizona and AMP Insights LLC), Alexis Morgan (WWF-Germany), Laura Turley (University of Geneva) and Aaron Vermeulen (WWF-Netherlands)

Design: Lou Clements

Spatial analysis and maps: Michele Daily (WWF-US) and Felipe Costa (WWF-Germany)

Thanks to the following people who contributed reviews or data: Michele Thieme (WWF-US), David Tickner (WWF-UK), Penny Beames (McGill University)

Please cite as: Opperman, J. J., S. Orr, H. Baleta, M. Dailey, D. Garrick, M. Goichot, A. McCoy, A. Morgan, L. Turley and A. Vermeulen. 2018. Valuing Rivers: How the diverse benefits of healthy rivers underpin economies. WWF.

ISBN: 978-2-940529-87-2

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EXECUTIVE SUMMARY

Though critical to all life – and to most economic activity – water has consistently been undervalued relative to the wide range of uses and benefits it provides. However, with new valuation methods and frameworks being developed, governments, the private sector and financial institutions are beginning to make progress in recognizing the wider value of water. As these discussions advance, we believe it is important to shine a light on a parallel and equally critical challenge: the consistent failure of economies and societies to value rivers for their full spectrum of benefits.

Traditionally, rivers have been valued primarily as water sources to drive the economic engines of irrigation and hydropower. However, rivers provide a broader set of services that deliver immense benefits to people, economies and nature, which include, but exceed, the value of the water they carry. But far too often, these benefits are not understood, recognized or valued and so are not a priority for river management – until clear problems emerge from their neglect.

- **Flood-risk reduction:** Functioning floodplains and healthy wetlands can reduce the risk of flooding for cities. But urban planners continue to prioritize development over natural flood defences, which has exacerbated recent floods in cities from Bangkok to Houston and paved the way for even worse disasters in the future.
- **Freshwater fisheries:** Rivers give life to some of the world's most productive fisheries but few decision makers fully appreciate the value of these freshwater fish – at least 12 million tonnes of which are caught each year – primarily because the extent to which this low-cost protein supports low income communities and boosts economies is neither well measured nor understood. Indeed, the global figure – already 12 per cent of the world's entire fish catch – is almost certainly a considerable under-estimate. As a result, decisions about river management, including the construction of dams that block fish migration, tend not to factor in the economic costs of losing this often forgotten source of food.
- **Sediment delivery:** The agricultural sector is always high on the agenda of governments, and the ability of rivers to provide water for crops has been prioritized, including massive investments in the infrastructure needed to dam and divert rivers for irrigation. And it has been hugely successful with around a quarter of the world's food production now dependent on river water for irrigation.

WE URGENTLY NEED TO STOP REGARDING RIVERS AS SIMPLY CONDUITS FOR MOVING WATER

In contrast, the critical capacity of rivers to deliver sediment and nutrients to sustain deltas – among the world's most productive agricultural regions and home to hundreds of millions of people – has remained a largely hidden benefit: undervalued and usually ignored when new dams, whose reservoirs capture sediment, are under discussion. Many of the largest deltas are now sinking and shrinking as a result – just as the world is warming and sea levels are beginning to rise.

Faced with rapid development, climate change and a world of increasing water risk, understanding these diverse values from rivers and then devising policies and practices to safeguard them is a formidable challenge. But we must rise to the challenge if we are to achieve the Sustainable Development Goals (Box 1). Indeed, this report shows that nearly a quarter of Gross Domestic Product (GDP) in Asia and a fifth of the GDP in Africa lies within watersheds with high to very high water risk (using a measurement of water risk that incorporates a range of values supported by rivers). Overall, 19 per cent of global GDP currently comes from watersheds with high to very high water risk.

To catalyze changes in policy and management, the value of rivers needs to be framed in terms that are compelling for those making decisions. 'Hidden' values can receive higher priority when they transcend environmental and social values and are translated into financial or economic values for key government agencies or influential private sector leaders.

Doing so will require a new framework for how rivers are valued and managed. This report adapts a recent framework for sustainable water management (Garrick et al. 2017), which describes the main components necessary for a new approach, including:

- **Measure:** Water resources generally, and rivers' benefits specifically, are often poorly monitored and measured. Sustainable river management requires greatly improved measurement of benefits, based on a rigorous understanding of key river processes and relationships. The so-called 'Fourth Industrial Revolution' offers a number of promising pathways to improve how we measure water and river systems.
- **Value:** Various methods have been developed, or are emerging, to improve the valuation of water and rivers' services, including rapid progress in quantifying ecosystem services. However, improved valuation methods will not have major impacts on policy and management unless this information is delivered to the necessary audiences in a format that they find compelling. For example, this report reviews the 'Rivers in the Economy' process, which directly engages diverse stakeholders and decision makers – including those from sectors not traditionally involved in water-management debates – to collectively discuss the contribution of rivers to societal benefits and economic gain. It also showcases the Water Risk Filter, which integrates 30 data layers (including many that capture rivers' diverse benefits) and translates those data into actionable information about risk for companies, investors or economies.
- **Understand tradeoffs:** Even with improved measurement and valuation of resources, decision making about river management will require navigating difficult tradeoffs. Decision science has recently produced new approaches to integrate a more diverse set of values into planning, management and policy decisions, illustrated by how tradeoff analysis can improve the sustainability of the hydropower sector.
- **Improve governance:** Implementing decisions and ensuring that progress is durable requires effective water-management institutions and governance, with roles for government (allocation policies), financial institutions (driving sustainable investment through bankable water solutions) and the private sector (context-based water targets).

We urgently need to stop regarding rivers as simply conduits for moving water and re-evaluate all the benefits of the rivers that flow through our communities, cities and countries. The growing economic profile of water creates a generational opportunity to do exactly this and to reconnect people with rivers – before more of their 'hidden' benefits are lost or degraded.

The framework in this report can help communities, river managers and decision makers in both the public and private sectors develop a better grasp of the diverse values that rivers provide and the need to collaborate to protect them.

1

INTRODUCTION

Water is the world's most precious resource but it is invariably undervalued relative to its wide range of uses and benefits. Globally, water resources are not managed in a way that reflects their full values – and this pattern of neglect has consequences. Poor management of water supplies has contributed to the decline of civilizations and continues to threaten the vitality and viability of communities, cities and countries today.[1]

New methods and frameworks are being developed to capture the wider value of water.[2] As this work advances, we believe it is important to shine a light on a parallel and equally critical challenge: *the consistent failure of economies and societies to value rivers for their full spectrum of benefits*.

The value of water and the value of rivers are intertwined but are not the the same. While rivers have primarily been regarded as sources of water for irrigation and hydropower, they provide a far broader set of benefits for people and economies. These benefits include – but exceed – the value of the water flowing down them.

Yet typically these benefits of naturally functioning rivers are not understood or valued, so they do not become a priority for decision makers - until they are lost. Indeed, these invisible values are invariably easier to quantify, and for politicians and river managers to appreciate, once they have been disrupted or destroyed (Box 2). For example:

- River floodplains and wetlands can reduce the risk of flooding for cities – an increasing concern in the face of climatc change.[3] The loss of floodplains and wetlands to urban development has exacerbated recent floods in cities from Bangkok to Houston.
- Rivers support the majority of freshwater fisheries, which produce at least 12 million tonnes per year - a figure that is almost certainly a sizeable underestimate.[4] But this is generally not a management priority – primarily because the extent to which low cost protein from freshwater fish supports vulnerable rural communities, enhances food security and boosts regional economies is neither well measured nor understood. As a result, decisions about river management, including the construction of dams and the disconnection of rivers from their floodplains by levees, tend to not factor in the economic costs of losing this vital source of food and livelihoods for hundreds of millions of people.
- Rivers deliver the sediment that maintains deltas, some of the most important agricultural regions in the world and home to 500 million people (approximately one out of 14 people on Earth[5]). In some rivers, nearly all sediment is captured within reservoirs or extracted by sand mining and many of the world's largest deltas are now sinking and shrinking due to insufficient sediment delivery – just as the seas are starting to rise.

These examples feature large-scale drivers, such as urbanization and infrastructure development, that are generally categorized as threats to rivers. Similarly, droughts and floods are perceived as threats to cities and companies. However, by better understanding and communicating the diverse values that rivers provide, these threats can also present opportunities. Healthy, functioning rivers and river basins can deliver risk reduction from floods and droughts that benefits communities and commerce, while urbanization and infrastructure projects can be planned strategically to ensure far lower impacts on rivers.

In the face of rapid development and climate change, understanding these diverse values and then devising policies and practices to safeguard them is a formidable challenge. Yet it is essential that we overcome obstacles to managing our resources better or the world will fail to achieve the Sustainable Development Goals (SDGs) (Box 1).

We believe we can overcome this challenge. Decision-makers increasingly recognize water's connections to the wider economy. Whether it's the World Economic Forum (WEF)'s annual ranking of water crises as one of the greatest threats to the global economy[6], or the UN SDGs[7] placing water at the heart of the global development and poverty agenda, or the US$70 trillion in the aggregate portfolios of investors who now ask global businesses to disclose their water risk and impacts[8], there is favorable momentum for action to ensure sustainable water supplies for people, business, and nature.

This growing economic profile for water creates a generational opportunity to reconnect people with rivers. The value of rivers can be bundled with the value of water; mechanisms and policies to value rivers can be modeled after, or coupled with, those aimed at valuing water. This opportunity cannot be missed; if water is going to finally come out of the shadows, we cannot allow rivers to remain in the dark.

1. VALUING RIVERS AND SUSTAINABLE DEVELOPMENT GOALS

In 2015, the United Nations agreed on a set of 17 Sustainable Development Goals (SDGs), encompassing 169 targets to be accomplished by 2030. This report's emphasis on the need to improve management for the diverse values of rivers echoes the overarching concept underpinning the SDGs: that economic, social and environmental values are intertwined and thus policies and management should pursue these values in a coordinated fashion.

SDG 6 focuses on water and encompasses a range of values for water, with sub-goals focused on water quality, equitable access, efficient use by various sectors, improved governance, and the protection and restoration of water-related ecosystems, including rivers.

The way the SDGs address water also illustrates the major theme of this report: the diverse values of water, and rivers, are embedded across a range of other economic and cultural values, beyond just the water sector. There are linkages between water and nearly every other SDG.[9] For example, water management is tightly coupled with SDG 2, for sustainable food production, particularly in Target 2.4.

While some of these linkages are widely recognized and thus reflected in the SDGs, others are not, with overlooked values including many of those provided by healthy rivers, such as the food value provided by river fisheries. While Target 14.4 measures the sustainable management of fisheries, it is found within SDG 14, which focuses on "oceans, seas and marine resources" – not freshwater systems.

2. COSTS OF FAILING TO VALUE AND MANAGE FOR RIVERS' DIVERSE BENEFITS

In temperate regions, rivers have been developed and managed for centuries, harnessed for navigation, energy and water supply. These developments were often done without long-range, strategic planning or any assessment of tradeoffs. Compounding the inevitable sub-optimal outcomes arising from such a lack of comprehensive planning, a range of river benefits remained unknown, poorly measured and undervalued.

As a consequence, river ecosystems and resources experienced dramatic declines in much of the industrialized world. Rivers served as waste disposal systems, resulting in widespread and often severe water pollution. The proliferation of water-management infrastructure, such as dams and levees, resulted in widespread fragmentation of rivers, disconnecting them from their productive floodplains and severing the routes used by migratory fish and other species.

Fish populations, already stressed by fragmentation and pollution, were harvested unsustainably, so that there are now very few commercially productive fisheries in temperate rivers. Many rivers in water-stressed regions have been so fully diverted that they no longer reach the ocean.

These same development trajectories of pollution, fragmentation and overharvesting are now playing out in rivers across the later-developing world.

The consequences of this approach to development and management are now reflected in a range of metrics reflecting river ecosystem health. Only a third of large rivers in temperate or tropical regions remain free-flowing[10] and at least 64 percent of wetlands across the globe have been lost since 1900[11]. Just 40 percent of Europe's waterways are in a good ecological state.[12] As a result of these dramatic changes to habitats, freshwater species have decreased alarmingly, with populations of freshwater vertebrate species tracked by the Living Planet Index declining by 81 percent since 1970, a far steeper fall than either terrestrial or marine species.[13] Of the 15,000 species of freshwater fish, the International Union for Conservation of Nature (IUCN) has so far assessed 5,685, with 36 percent of those now classified as threatened on the Red List.[14]

Due to upstream removal of sediment by mining and capture within reservoirs, many of the most productive and populated rivers deltas around the world are rapidly shrinking, including those of the Mekong, Nile, and Mississippi Rivers.[15]

Furthermore, partly due to river management focused on narrow or short-term objectives, water risk now looms over economies across the world (see Figure 7 in Section 3) – a risk that will be exacerbated by climate change, including likely impacts such as increased evaporation and intensity of storms.

Note that pollution from many sources has declined dramatically in rivers in North America and Europe, largely in response to an expanding set of societal values for water and rivers. This trajectory illustrates how policy regimes and corporate practices can reflect evolving perceptions of the value of water and produce impressive results.

James Suter / Black Bean Productions / WWF-US

A FRAMEWORK FOR VALUING WATER AND VALUING RIVERS

To catalyze changes in policy and management, the value of rivers needs to be framed in terms that are compelling for those making decisions. Rivers have traditionally been valued as providers of water supply or hydroelectric power. But the full value of rivers is far larger and includes a set of benefits that are often invisible to decision makers. These 'hidden' values are generally not measured or prioritized until crises arise.

The persistent failure to proactively manage to maintain these broader river values – such as the delivery of sediment to sustain deltas, freshwater fish stocks and flood mitigation – has resulted in dramatic and widespread social, environmental and economic losses (Box 2).

Water-management infrastructure built for hydropower, flood control, or water storage has produced substantial benefits for economies, but often at the cost of a dramatic reduction in other benefits from rivers. The premise of this report is that many of those losses were not, and are not, inevitable collateral damage that must be accepted as the price of progress. River management that rests on a foundation of understanding and valuing rivers for their diverse benefits can produce much more balanced and sustainable outcomes.

Doing so will require a new framework for how rivers are valued and managed. Here we adapt a recent framework for sustainable water management[16], which describes the components necessary for such a new approach.

1. MEASURE

"You can't manage what you don't measure" is a classic adage for business, and water management is plagued by a lack of measurement of key attributes. The 'hidden' values of rivers are even less well monitored – and often not well understood. Thus, improved valuation and management first require an understanding of how key river processes create benefits coupled with significant improvements in the measurement of water flows and stocks, watershed conditions, and a range of biophysical processes, such as sediment transport, as well as social, economic and cultural dependencies on rivers. The so-called "Fourth Industrial Revolution" (or 4IR) offers a number of promising pathways to improve how we measure water and river systems, and catalyze new mechanisms for valuing water and optimizing multiple benefits.

2. VALUE

Water is an inherently difficult resource to value as it encompasses both market and non-market values. Rivers' 'hidden' services can be even more difficult to value. The benefits from traditional uses of rivers (e.g., hydropower and irrigation) are often easy to monetize and accrue to well-defined interests, while many of their costs are externalized. Conversely, the broader benefits from rivers are often diffuse, distributed and poorly defined – and are difficult to quantify or monetize. Various methods have been developed, or are emerging, to improve the valuation of water and rivers' services. While quantifying value is an important step, we believe that how and to who rivers' values are communicated are as, or more, important than the numerical quantification. To influence decision makers, rivers' values must be framed as relevant to the broader economic trends and sectors they prioritize, such as economic growth and financial returns. In other words, they cannot remain siloed as 'environmental' and the decision makers that pay attention to them cannot be restricted to those within the water and environmental ministries. Instead, broader river values need to be on the agenda of those who manage energy, agriculture and urban risk, as well as a wider range of influential actors within the private sector. Currently, many sectors do not realize how dependent they are on rivers and how much their sustainability or business models are at risk if rivers are mismanaged. Helping these sectors understand that linkage will diversity the voices calling for more sustainable management of rivers.

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3. UNDERSTAND TRADEOFFS

Even with improved information, decision making will require navigating difficult tradeoffs, often across market and non-market values. Decision science has recently produced new approaches to integrate a more diverse set of values into planning, management and policy decisions. For example, multi-objective analysis can encompass a range of values in different units, thus not requiring all resources to be monetized. Rather, the analyses strive to make clear the tradeoffs associated with different development and management options. These results can be used by different stakeholders to understand how various options would affect them and to advocate for those options that best address their objectives. Decision makers can strive to identify those options that work relatively well for a range of resources and stakeholders.

4. IMPROVE GOVERNANCE

Implementing decisions and ensuring that progress is durable requires effective water-management institutions and governance. Governance includes, but goes far beyond, government agencies and policies. It also encompasses financial policies and mechanisms to incentivize sustainable investment decisions as well as private sector policies and practices, along with informal governance mechanisms such as water user associations. It is critical to also involve stakeholders who are not currently engaged in governance of rivers and unaware of how much they could benefit in the long run by participating. In this report, we explore examples of governance mechanisms intended for regulatory and planning ministries (water allocation and system planning for energy and water infrastructure), the private sector (Context-based Water Targets and certification) and financial institutions (“bankable water solutions” for promoting sustainable water and river management).

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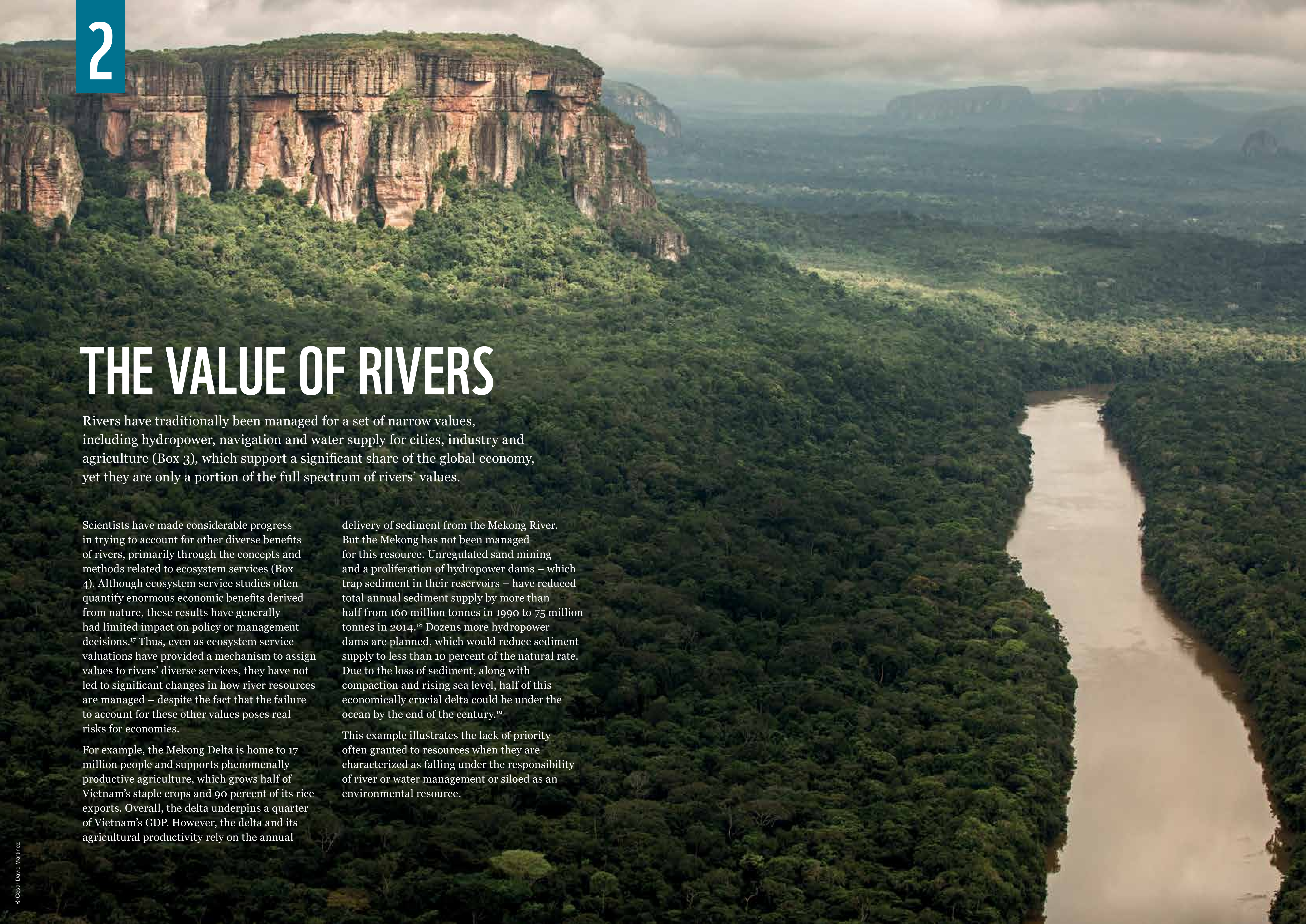
Valuing Rivers



2

THE VALUE OF RIVERS

Rivers have traditionally been managed for a set of narrow values, including hydropower, navigation and water supply for cities, industry and agriculture (Box 3), which support a significant share of the global economy, yet they are only a portion of the full spectrum of rivers' values.

Scientists have made considerable progress in trying to account for other diverse benefits of rivers, primarily through the concepts and methods related to ecosystem services (Box 4). Although ecosystem service studies often quantify enormous economic benefits derived from nature, these results have generally had limited impact on policy or management decisions.[17] Thus, even as ecosystem service valuations have provided a mechanism to assign values to rivers' diverse services, they have not led to significant changes in how river resources are managed – despite the fact that the failure to account for these other values poses real risks for economies.

For example, the Mekong Delta is home to 17 million people and supports phenomenally productive agriculture, which grows half of Vietnam's staple crops and 90 percent of its rice exports. Overall, the delta underpins a quarter of Vietnam's GDP. However, the delta and its agricultural productivity rely on the annual delivery of sediment from the Mekong River. But the Mekong has not been managed for this resource. Unregulated sand mining and a proliferation of hydropower dams – which trap sediment in their reservoirs – have reduced total annual sediment supply by more than half from 160 million tonnes in 1990 to 75 million tonnes in 2014.[18] Dozens more hydropower dams are planned, which would reduce sediment supply to less than 10 percent of the natural rate. Due to the loss of sediment, along with compaction and rising sea level, half of this economically crucial delta could be under the ocean by the end of the century.[19]

This example illustrates the lack of priority often granted to resources when they are characterized as falling under the responsibility of river or water management or siloed as an environmental resource.

The delivery of sediment to the Mekong Delta by the river should be viewed as a critically important resource to those responsible for Vietnam's agriculture, food security, urban safety and economic development more broadly. The importance of sediment to the delta is becoming a greater priority, but Lower Mekong countries' past decisions on hydropower dams and current allowance of large-scale sand mining do not reflect the true value of sediment. Moreover, current basin-wide governance structures do not support more sustainable management of sediment across borders or provide a mechanism to implement tradeoffs between Vietnam and the upstream Mekong countries.

Rivers' 'hidden' values can receive greater policy priority when they transcend environmental and social values and are translated into financial or economic values for key agencies or influential private sector leaders. For example, Myanmar's Irrawaddy River is the largest source of freshwater capture fisheries in a country where fish are by far the largest source of protein. Though not well monitored, the value of fisheries from the Irrawaddy could be valued in the billions of US dollars annually (based on extrapolation from the neighbouring Mekong River), yet the threat to these crucial wild fisheries from dams does not appear to have been a major concern during the planning of hydropower developments – possibly because the value of fisheries are relatively diffuse, accruing largely to rural people with much of the value falling outside formal markets. Furthermore, the economic and environmental costs of alternative protein production have generally not been considered either.

However, Myanmar is moving toward a strategic planning approach for hydropower with early indications that the Irrawaddy mainstem could be protected from dam development. This planning approach arose in large part because a set of diffuse cultural, social and environmental river values for the Irrawaddy were translated into investment risk. Social protest over the proposed Myitsone hydropower dam resulted in a multi-year suspension and likely cancellation – after the developer had invested US$800 million. It is the threat of further social unrest and investment risk that is driving the move towards more strategic planning for hydropower in Myanmar, rather than the need to maintain ecosystem services such as fisheries or sediment transport. However, the system planning that may be driven by this attention to tangible financial values is much better positioned to measure and value a variety of ecosystem services and to strive to promote those through more inclusive decision making (options assessments, tradeoff analyses etc.) and governance mechanisms.

Below we summarize a set of river services and resources that have traditionally been undervalued. For each we describe how the values are produced from rivers as complex biophysical systems – that is, how these are river values that transcend the value of water in the river. We also review how these values can be translated into financial or economic values that are likely to be important to key audiences in government, finance or the private sector. While a major theme is how rivers' values can be translated into financial and economic terms, we also emphasize that these values cannot, and should not, be limited to inputs to cost-benefit analyses, and include a broad range of recreational, cultural and spiritual values (see Box 5).

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3. TRADITIONAL USES OF RIVERS

Rivers have traditionally been valued, and thus managed, for a relatively narrow set of uses, including hydropower, water for irrigation and cities, navigation and flood control.

While these uses have contributed to economic growth, they have also been the primary causes of substantial social, environmental and economic losses (see Box 2). The premise of this report is that many of those losses were not, and are not, inevitable collateral damage that must be accepted as the price of progress. River management that rests on a foundation of understanding and valuing rivers for their diverse benefits can produce much more balanced and long-lasting outcomes. However, these traditional uses will continue to be important management goals for rivers and thus reconciling these uses with maintaining and restoring healthy rivers is the essential challenge for river management.

- Through hydropower, rivers provide 17 percent of global electricity generation (Figure 1).[20]
- Through developed irrigation systems, rivers irrigate 190 million hectares of land, or 62 percent of all irrigated land (Figure 2). With irrigated land accounting for 40 percent of global food production[21],this means rivers directly support approximately a quarter of global food production. However, this figure does not include river fisheries nor the lands supported by flood-recession agriculture, which collectively feed hundreds of millions of people.
- While the number of people whose drinking water comes from rivers has not been estimated precisely, it is likely that about half the world's population depends on surface water supplies, with the rest depending on groundwater[22] – though note that in many places, groundwater and surface waters interact. For this report, we conservatively estimate that approximately 2 billion people receive their water from water-supply reservoirs created by damming rivers (Figure 3).[23]

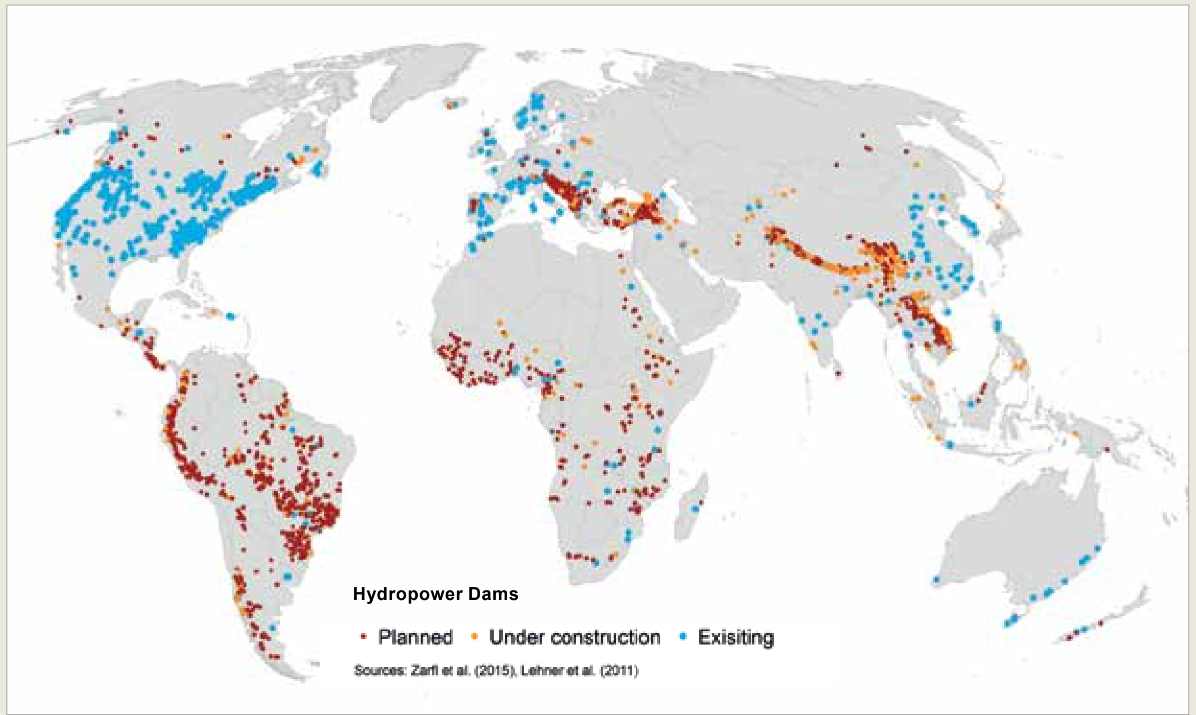


Figure 1: *Global hydropower dams (existing, under construction and planned); Data on existing dams from Global Reservoirs and Dams Database (GRanD)[24], under construction and planned dams from Zarfl (2015)[25]*

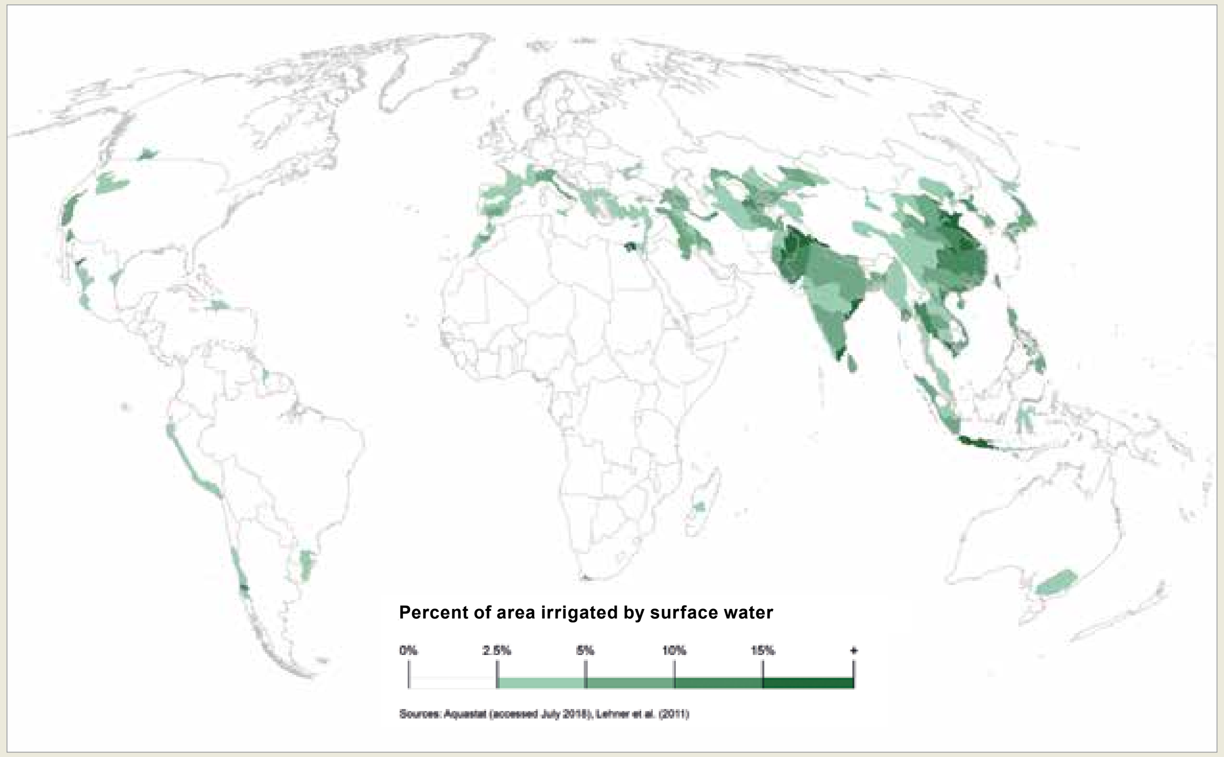


Figure 2: *Lands irrigated from river-based systems. Percentage of river basin area (Hydrosheds Level 4) irrigated from a river source (data from IWMI Global Irrigated Area Mapping)[26]*

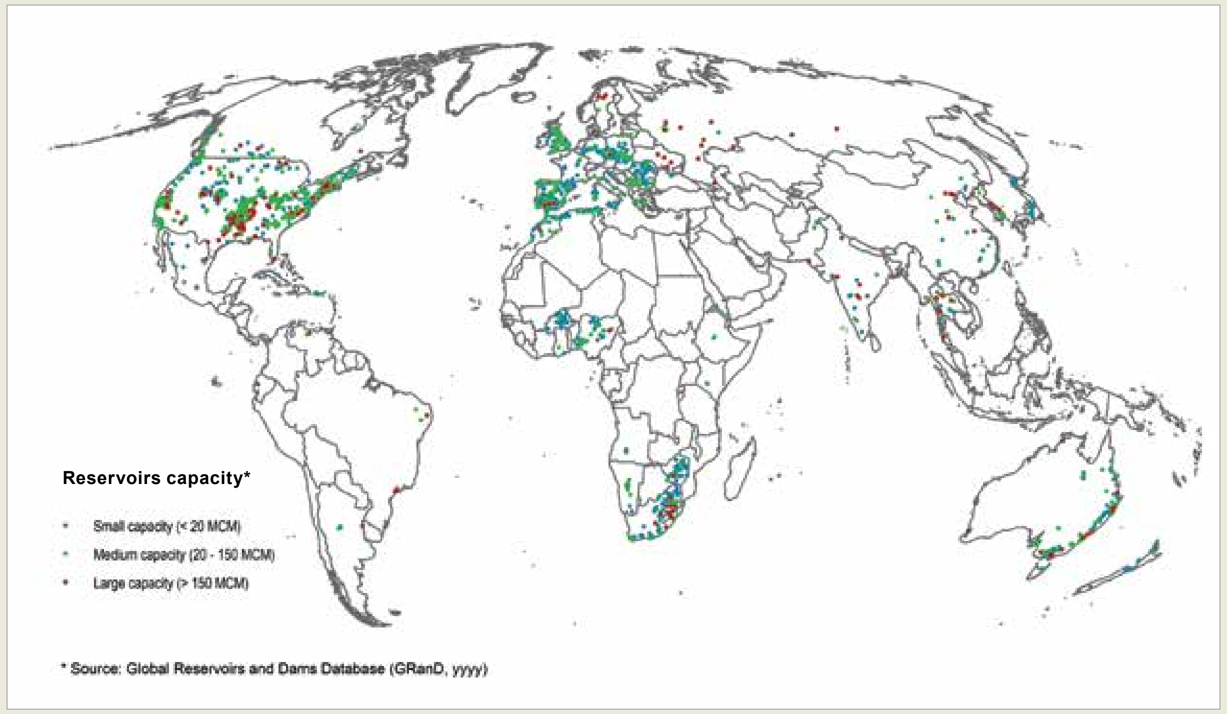


Figure 3: *Reservoirs in the GRanD database with water supply listed as a purpose (see endnote 23 for data sources and methods)*

2.1

WATER FROM RIVERS AND RIVER BASINS

CLEAN SUSTAINABLE WATER SUPPLIES

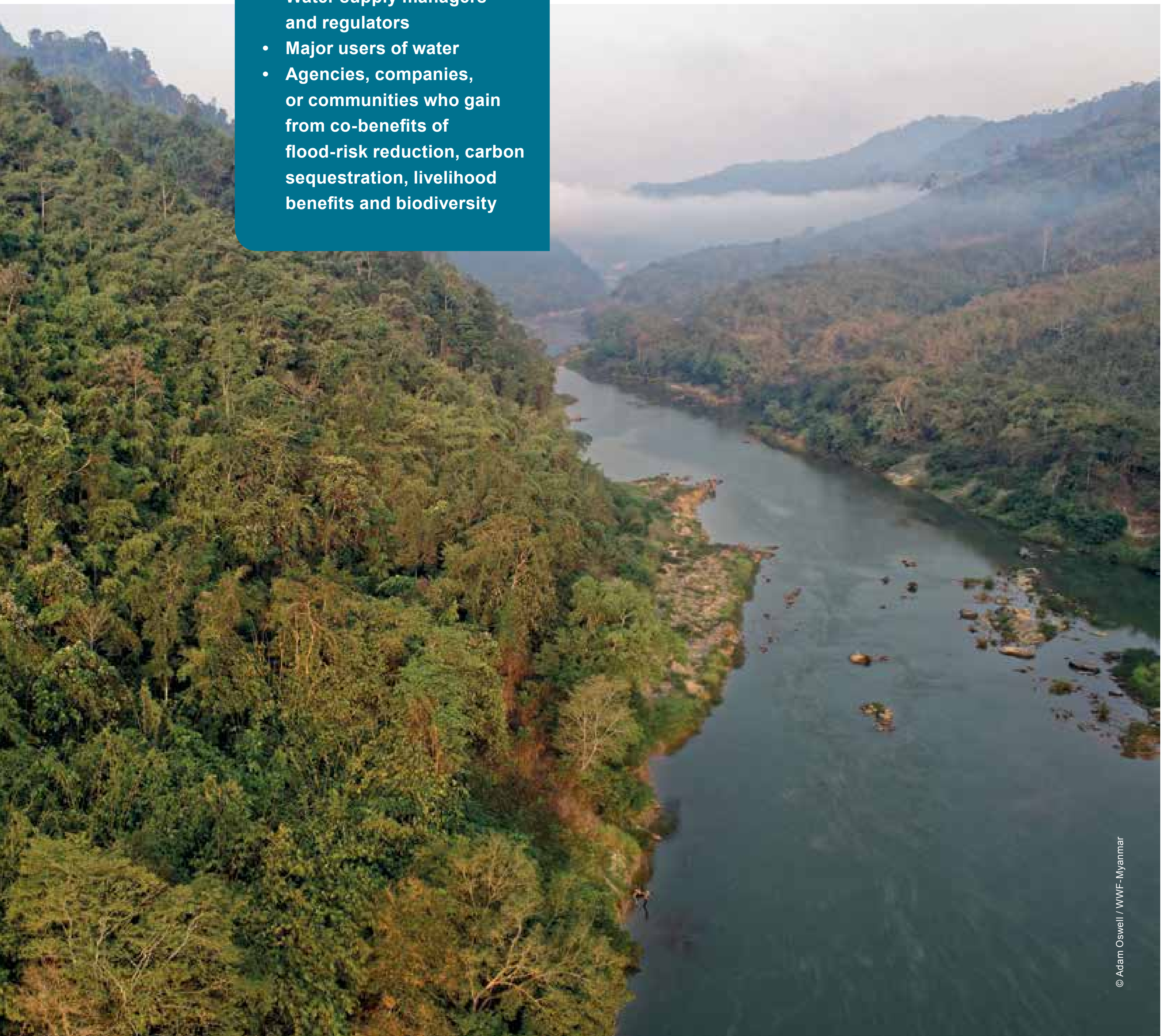
The value from functioning rivers:

- **Diverse features of healthy river basins – encompassing forests, wetlands, and floodplains – contribute to the delivery of clean and stable water supplies**

Key audiences:

- **Water supply managers and regulators**
- **Major users of water**
- **Agencies, companies, or communities who gain from co-benefits of flood-risk reduction, carbon sequestration, livelihood benefits and biodiversity**

Globally, the demand for water has been increasing at approximately 1 percent per year and demand will continue to grow due to shifting patterns of consumption (e.g., toward more meat in diets) and population growth.[27] Studies consistently forecast a shortfall between supply and demand and, in much of the world, climate change will likely exacerbate these challenges. For example, Schlosser et al. (2014) predict that just over half the world's population will live in regions with water stress by 2050.[28]



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The majority of the world's irrigation water and much of the world's urban water supply comes from river systems.[29] In the United States, two-thirds of cities receive their water supplies from rivers, such as the Colorado, which supports 36 million people in cities that span seven states, from Denver to Los Angeles.[30] Globally, the number of people who depend on rivers for their water reaches the billions (see Box 3).

Natural features of rivers and their basins – 'green infrastructure' – are critical to maintaining the flows of clean water that these billions depend on. For example, forested watersheds with deep soils promote infiltration and, by reducing excess surface erosion, decrease the amount of sediment and associated nutrients that enter water supplies. Wetlands, particularly in agricultural regions, can also play an important role in reducing the amount of excess sediment and nutrients entering water systems. Healthy floodplains can promote groundwater recharge and have the potential to be managed in conjunction with water-management reservoirs.

While engineered infrastructure is obviously critical to water-supply systems, managers generally underinvest in the green infrastructure within river basins that improves the performance of reservoirs and water treatment plants. Instead, investments focus on engineered infrastructure, such as bulk water storage, groundwater pumping or, in some cases, desalination when systems become strained and degraded.

The 2018 World Water Development Report[31], from UN Water, emphasizes that nature-based solutions should play a central role in how the world manages water supplies in the context of growing demand and climate change. The report recommends a range of nature-based solutions, including using natural features to increase water availability (e.g., recharging groundwater and retaining water in soils) and using wetlands to improve water quality.

Cape Town provides a compelling example. The South African city suffered a historic drought, receiving global media coverage for how close it came to running out of water.

While investing in some forms of engineered infrastructure – from additional reservoirs to groundwater pumping and desalination – are necessary, the region can also invest in nature-based solutions to improve its water supply. For example, in the watersheds that supply Cape Town's water, restoration of native vegetation can increase available water. Non-native species, such as eucalyptus, are 'thirstier' than the native plants they have replaced, sucking up through their roots and evaporating an additional 1.4 trillion litres of water per year. This loss is equivalent to 4 percent of the nation's water supply (and because non-natives are spreading, the loss could quadruple to 16 percent).[32]

Removing non-native plants, and restoring native vegetation, as WWF-South Africa has been doing in the Riviersonderend watershed, is therefore part of the solution for ensuring adequate water supplies – at a cost comparable to, or lower than, many other alternatives.[33] The broader effort of clearing non-native vegetation to boost waters supplies has also employed tens of thousands of people, an important co-benefit in a country with 26 percent unemployment.[34]

A corollary to the benefits of restoring green infrastructure is the impacts that occur when it is lost, for example through widespread clearing of forests and land degradation in a river basin. These conditions can lead to dramatically higher rates of erosion and lead to excessive buildup of sediments in channels, increasing flood risk and negatively impacting navigation. Investing in green river infrastructure can help reduce these risks as well as boosting water supplies.

FLOOD PULSE ADVANTAGE

The value from functioning rivers:

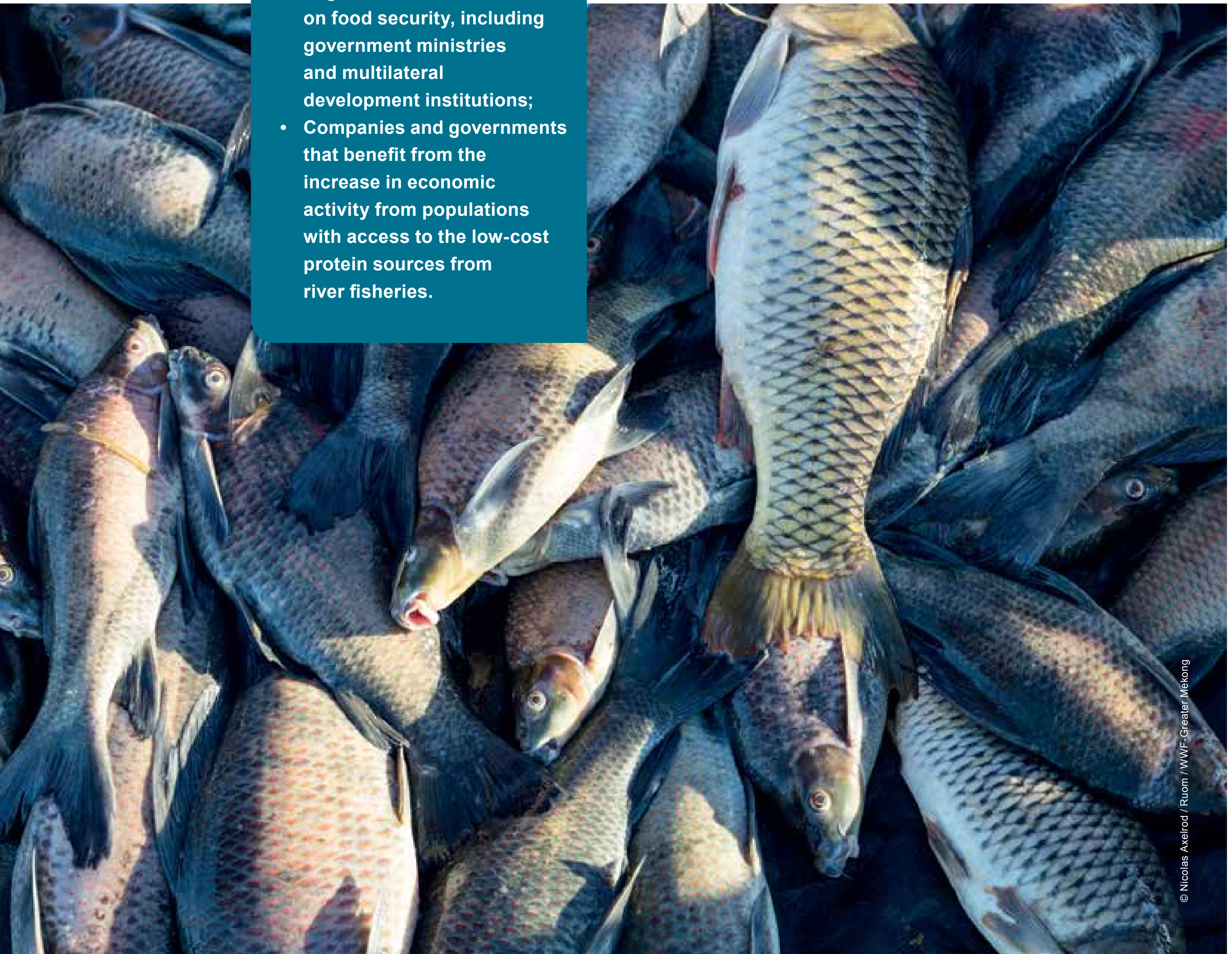
- **The high productivity of many river fisheries depends directly on a set of natural features and processes: longitudinal connectivity for migratory fish, extensive floodplains connected to the river and a natural flow regime that can periodically inundate those floodplains. Rivers with these natural features are far more productive than freshwater systems that lack them (the flood-pulse advantage).**

Key audiences:

- **Organizations focused on food security, including government ministries and multilateral development institutions;**
- **Companies and governments that benefit from the increase in economic activity from populations with access to the low-cost protein sources from river fisheries.**

RIVER FISHERIES

Rivers, particularly those that retain a natural flow regime and connectivity with floodplains, support some of the largest freshwater fish harvests in the world. The Mekong River's fishery has an annual harvest that exceeds 3 million tonnes, valued at US$17 billion per year.[35] Capture fisheries represent 18 percent of Cambodia's GDP and 13 percent of Laos' GDP. Myanmar's freshwater fisheries, dominated by rivers such as the Irrawaddy, produce more than 1.3 million tonnes of fish per year and employ approximately 1.5 million people. River fisheries provide important sources of protein and nutrients in a number of other regions and river basins, including the Amazon, and across South Asia and Africa.[36]



Globally, river fisheries provide the majority of the nearly 12 million tonnes of freshwater fish harvested per year, sufficient to provide the primary source of protein for at least 160 million people.[37] River fisheries provide livelihoods for 60 million people, with 55 percent of those being women. These global estimates are derived from official harvest statistics and thus are no doubt very conservative estimates because river fisheries are generally underreported. Lymer et al. (2016) estimated the theoretical global freshwater harvest levels based on estimates of total area of various freshwater habitat types and average yield data from those habitat types and found that total harvest is likely considerably larger than official estimates.[38] Actual river harvests may be 50 to 100 percent larger than estimates derived from official statistics, suggesting that river harvests are sufficient to provide the primary source of protein for a third of a billion people.

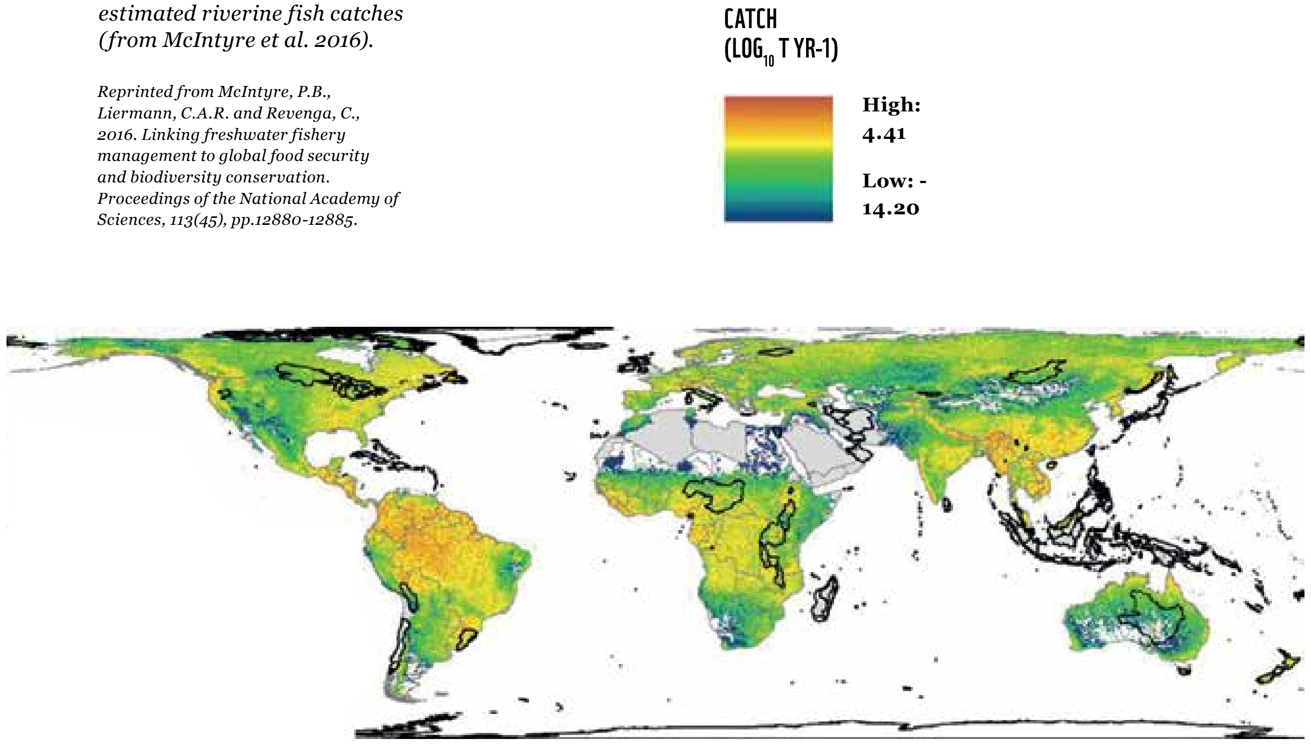
In addition to food production, river fisheries can provide important recreational values. Globally, recreational freshwater fisheries are estimated to have a non-market use value between US$65-80 billion per year.[39]

The most productive freshwater fish habitats in the world are rivers that retain a natural flood pulse and connection to expansive floodplains. Bayley (1995) describes river-floodplain ecosystems as having a 'flood-pulse advantage', which refers to the significantly greater per-unit-area production of fish within rivers with a dynamic flow regime and connectivity with a floodplain compared to rivers or reservoirs lacking such connection via a flood pulse.[40] Thus, it is the dynamic processes of rivers that retain natural characteristics that drive the most productive freshwater fisheries.

Sustaining this productivity requires maintaining (1) a flow regime that includes a flood pulse, which inundates floodplains; (2) connectivity between a river and its floodplains; and (3) up and down-stream connectivity because many river harvests are dominated by migratory fish. Yet, only a third of large rivers in temperate or tropical regions remain free flowing and many of those are now threatened by dams and infrastructure.[41] The health and sustainability of freshwater fish stocks seldom appear to be factored into these river development plans, despite the hundreds of millions of people who rely on them and their sizeable economic benefit.

Figure 4:
Gridded global map of estimated riverine fish catches (from McIntyre et al. 2016).

Reprinted from McIntyre, P.B., Liermann, C.A.R. and Revenga, C., 2016. Linking freshwater fishery management to global food security and biodiversity conservation. Proceedings of the National Academy of Sciences, 113(45), pp.12880-12885.



SEDIMENT SUPPLY TO MAINTAIN RIVER BANKS, COASTAL DUNES AND DELTAS

River sediments, particularly sand and gravel, are natural resources shaped by and transported through river systems. Their benefits are hidden from view, nourishing floodplains and fisheries, and bringing stability to river banks as well as providing one of the most important benefits to society – building and maintaining the world's great river deltas.

Sediment is lost when blocked by infrastructure (mainly dams) or mined. In some river basins up to 98 percent of sand is trapped in reservoirs.[42] Globally, nearly a quarter of annual sediment flux is now captured by them.[43] In addition, sand mining constitutes the largest mined resource on the planet.

Rivers' total sediment loads tend to be dominated by silts and clays, while the coarse sediment (sand and gravel) usually represents the smallest volume. Yet these coarse sediments play a disproportionate role in the functioning of the river system in terms of the shape and structure of the channel. These sediments are the grain sizes most effectively captured by reservoirs and the ones targeted for mining.

Between 32 and 50 billion tonnes of aggregate (sand and gravel) are extracted globally each year.[44] Rivers are the preferred source because they grind rock into sand and gravel and deposit them in patches sorted by size (e.g., fine sand, small gravel) so miners do not have to perform the costly activities of grinding and sorting. Major markets for sand – cities with high demand for construction materials – are often located along rivers, keeping transport costs low. Furthermore, sediment produced by rivers tends to have an angular shape preferred for construction materials.

The benefits derived from mining this inexpensive resource from rivers are evident to the construction industry, but the present market cost of sand and gravel does not reflect the environmental and social price of the commodity, especially when the cumulative impacts of sediment loss due to dams and sand mining are considered. A reduction in a river's coarse sediment load increases riverbank erosion with the associated loss of property, agricultural land and infrastructure, including roads, and sometimes the failure of levees and bridges in areas where infrastructure cannot be anchored on bedrock. Sediment depletion can result in a lowering of the main channel, which can reduce the frequency of flooding. While flooding is generally perceived as a problem, moderate floods can provide a range of benefits, including boosting the productivity of fisheries, fertilizing croplands with nutrient-rich sediment, and removing accumulated salts or pests from fields. Furthermore, channel incision leads to a lowering of the water table on the floodplain, affecting water availability for both people and ecosystems.

Removing sand from rivers also reduces the amount flowing into the oceans and along the coast, leading to a corresponding loss of coastal sand dunes, which act as a natural buffer, protecting people and property from natural disasters, such as tropical cyclones and storm surges.

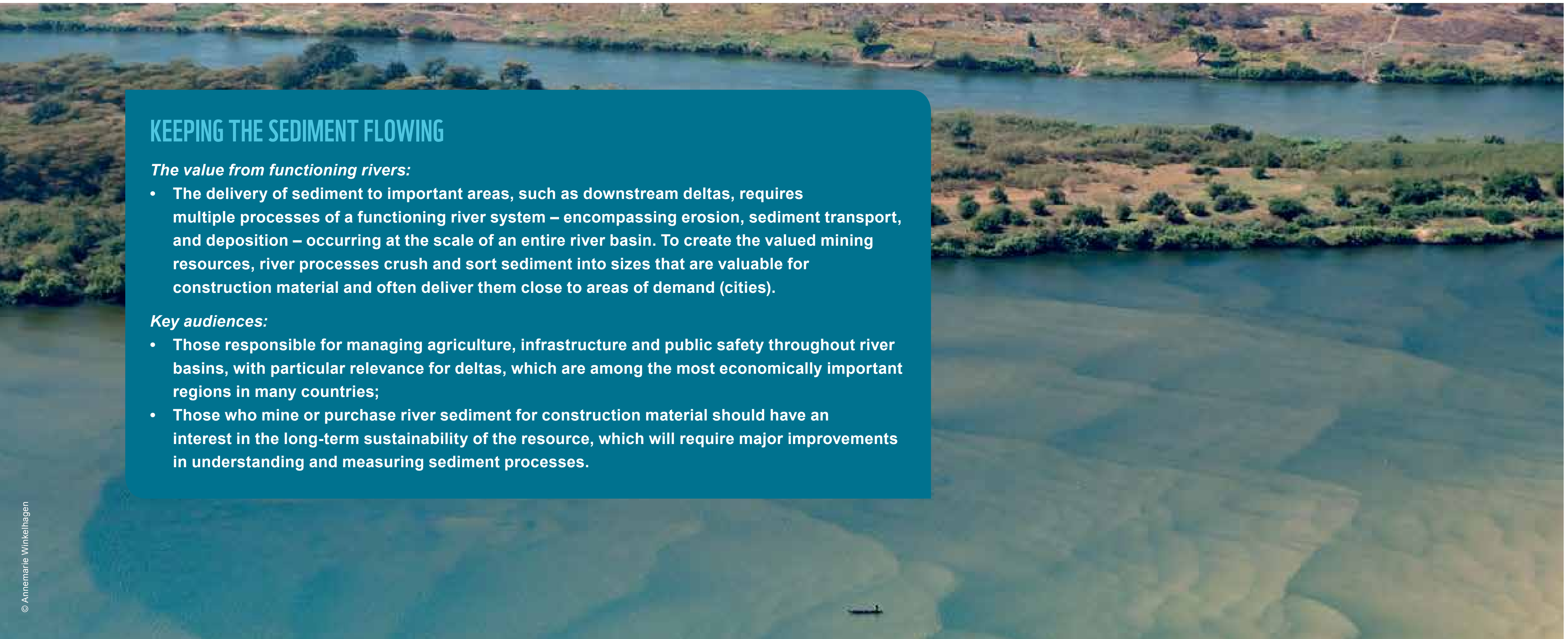
However, it is the increasing vulnerability of the world's great river deltas – home to 500 million people – that is the most problematic impact of the widespread loss of river sediment. With a high sediment supply, deltas can remain above water, counteracting the rising sea levels caused by climate change. But insufficient sediment supply will see a delta start to shrink, losing valuable agricultural land to the seas, contributing to the intrusion of salty water into the groundwater and exposing inhabitants to greater risk from storms.

As a consequence of high levels of sand mining and reservoir capture, the amount of sediment reaching many deltas has declined drastically, including the Mekong, the Yangtze, and the Ganges-Brahmaputra-Meghna deltas, with an average drop of nearly 90 percent: all these deltas are now shrinking.[45]

The Mekong River provides an instructive example of the implications of sediment loss for a productive delta. The river's total average natural load is estimated at 160 million tonnes (Mt) with the coarse load estimated to be less than 30Mt. But current sand mining volumes are above 50Mt – clearly far beyond a sustainable rate. As a result of sediment depletion, rates of erosion of the river bed and the delta's coastline have increased substantially, with the delta now losing an area equivalent to one and a half football fields every day on average.[46] If all the proposed hydropower dams are built, sediment supply will fall to less than 10 percent of the natural rate; the consequences for the Mekong Delta – critically important to Vietnam's society and economy – will be dire.

River sediment has been undervalued for far too long. Dam planning needs to consider the impact on sediment flows, while the market cost of sand should include the investments required to maintain river banks and associated infrastructure and to keep deltas from sinking and shrinking.

The extremely high value of many of the world's river deltas, in terms of population, agricultural productivity and GDP, makes a strong case for maintaining sediment flows in rivers as the most effective measure to mitigate the impact of climate change on deltas. While mining of river sediments could likely be managed and regulated to maintain a sustainable delivery to downstream areas, current understanding of the processes of sediment production, transport, and delivery to deltas and delta stability is relatively limited for most river systems. Thus, setting sustainable guidelines for sand mining will require significant improvements in our understanding of basic processes along with improved measurement.



KEEPING THE SEDIMENT FLOWING

The value from functioning rivers:

- **The delivery of sediment to important areas, such as downstream deltas, requires multiple processes of a functioning river system – encompassing erosion, sediment transport, and deposition – occurring at the scale of an entire river basin. To create the valued mining resources, river processes crush and sort sediment into sizes that are valuable for construction material and often deliver them close to areas of demand (cities).**

Key audiences:

- **Those responsible for managing agriculture, infrastructure and public safety throughout river basins, with particular relevance for deltas, which are among the most economically important regions in many countries;**
- **Those who mine or purchase river sediment for construction material should have an interest in the long-term sustainability of the resource, which will require major improvements in understanding and measuring sediment processes.**

FLOOD-RISK REDUCTION

Forecasts suggest that even relatively small rises in the global average temperature will result in an increase in the frequency of intense and damaging storms and floods (Figure 5) and the modeled predictions are already being confirmed with real-world disasters.[47] In addition to rising risk from climate change, the number of people threatened by flooding is also growing due to continued migration into flood-prone areas: nearly half of all urban development between today and 2030 will occur within areas with elevated risks of flooding.[48]

MITIGATING DISASTERS

The value from functioning rivers:

- Floodplains provide flood-risk reduction when they remain connected to rivers, providing room for storage and conveyance of floodwaters; this connectivity also drives numerous other benefits from rivers, such as fisheries productivity and groundwater recharge.

Key audiences:

- Flood management agencies;
- Farms, communities and the companies or governments that insure or compensate for flood losses; and
- Those who gain from co-benefits, including groundwater recharge, nutrient sequestration, and recreational opportunities.

That's an additional 500,000 square kilometres of urban development – an area the size of Spain – that will be at risk of floods. In places where governments have invested in flood defenses, the structures, such as dams and levees, are often deteriorating and budgets are insufficient to keep up with the growing backlog of repairs and maintenance.

Furthermore, ongoing changes in river basins – including conversion of forests and wetlands into agriculture land and the expansion of urban areas dominated by impervious surfaces – are increasing the size and frequency of floods.

All too often, debates about where to invest in flood-risk management focus strictly on engineered structures, such as dams, levees, and floodwalls. However, a consensus is emerging that a much broader approach – a 'diversified portfolio' – is needed to manage current and future flood risks.[49] This portfolio should emphasize non-structural measures such as improved zoning, building codes and insurance, as well as strategic investment in an under-appreciated line of defence: river floodplains as green infrastructure to reduce flood risk.

Green infrastructure uses nature's regenerative forces to mitigate and manage the forces of nature that threaten lives and property. Examples range from simple 'green roofs' – vegetation planted on top of buildings that soak up rainwater and reduce runoff of urban storm-water – to complex floodplains that are maintained, or reconnected to rivers.[50] The 60,000 acre Yolo Bypass in California's Sacramento Valley – a vast area of floodplain that was reconnected to the Sacramento River nearly a century ago (see photo on opposite page) – provides an effective demonstration of the potential for large-scale reconnection of floodplains to help manage flood risk for cities and farms.[51] The Bypass conveys nearly 80 percent of flood volumes during major storms, reducing the flood risk as the Sacramento River flows past its namesake city, which it has a long history of flooding.

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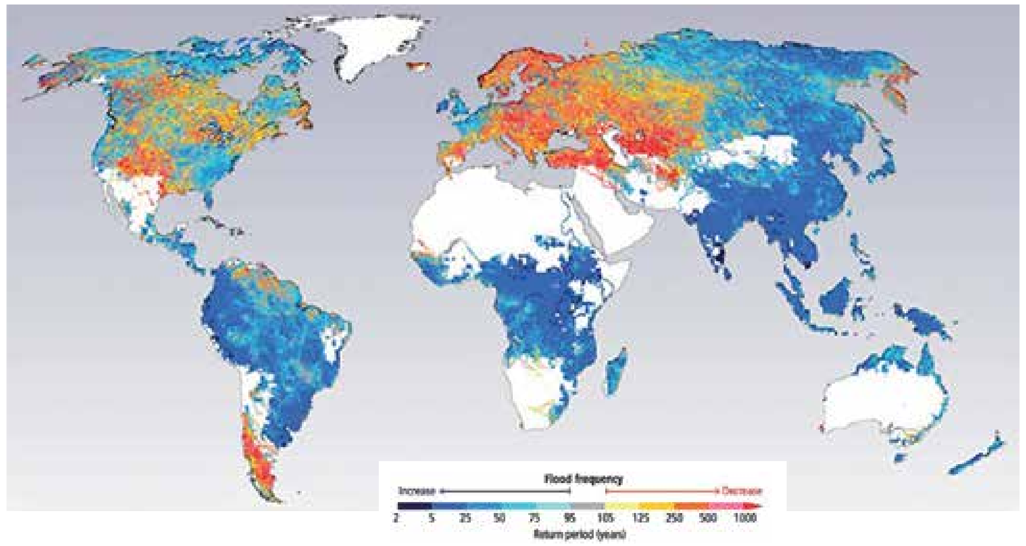

Reprinted by permission from Springer Nature, Nature Climate Change, Global flood risk under climate change, Yukiko Hirabayashi et al. 2013.

Figure 5: *Modeled changes, based on a combination of multiple climate models, in the frequency of what is today considered a "100-year flood" (i.e. a rare flood with a 1% chance of occurring in any given year). Blue colors indicate areas where the river discharge associated with a 100-year flood will become more frequent by 2071; for example, the dark blue areas will see a flood the size of today's 100-year flood several times a decade, or with a 20 to 50% chance of occurring in any given year. Red-orange colors indicate areas where floods will become less frequent. Many highly populated areas are forecast to see an increase in flood frequency, including the west coast and much of the midwest and eastern United States, most of Latin America, northern Europe, most of Africa and heavily populated India, Southeast Asia, China and Indonesia.*

In addition to providing the benefit of flood-risk reduction, the green infrastructure of floodplains also supports another, generally hidden, value from rivers: the productivity associated with natural flooding. Floodplains are among the most productive and diverse habitats on the planet and these values are supported by periodic flooding from the river.

Engineered infrastructure generally strives to alter natural processes and, as a result, structures such as dams and levees are among the leading causes of the loss of floodplain productivity and the habitats and fish and wildlife. Green infrastructure, on the other hand, works with natural processes and so provides multiple benefits, ranging from habitat protection to groundwater recharge and carbon sequestration. For example, though it was built by engineers strictly for flood management, the Yolo Bypass provides the best remaining lowland floodplain habitat in the Central Valley, supporting vast flocks of native birds and providing rearing habitat for endangered fish species such as salmon.[52]

To be clear, we are not suggesting that healthy floodplains are *the* answer to reducing current and future risk. Rather, they offer some distinct advantages within a diversified portfolio approach to flood management and should be part of the solution.

Countries that have not yet invested heavily in flood management systems can fully consider the benefits of incorporating green infrastructure when they do begin to invest. There are numerous examples – the Sacramento Valley, the lower Mississippi, the Netherlands – where engineers originally tried to fully contain rivers within levees, only to realize, in the face of repeated floods, that the river would need some room to spread out during the largest floods. So in each place they have now reconnected rivers to their floodplains in key areas. Later developing countries can avoid these mistakes and 'get it right' the first time by pursuing a diversified portfolio and taking maximum advantage of the multiple benefits of existing floodplains.

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4. RIVERS' ECOSYSTEM SERVICES AND NATURAL CAPITAL

The concepts of natural capital and ecosystem services have been developed to more effectively capture the diverse range of products, services and benefits provided by natural ecosystems, including rivers.[53]

Natural capital refers to the various components of ecosystems, both living and nonliving, that underpin the production of goods and services. Ecosystem services refer to the products and services that are generated by natural ecosystems and that benefit people. Among global ecosystem types, rivers and river-dependent ecosystems – such as floodplains and estuaries – supply among the greatest per-hectare value of ecosystem services.[54] Rivers and associated ecosystems provide a broad range of services, including clean water, sediment, fisheries, and the regulation of flood flows. Other riverine ecosystem services include carbon and nutrient sequestration, fiber production, biodiversity, and a range of cultural, spiritual and recreational values (see Box 5).

The methods and tools to quantify ecosystem services have been evolving rapidly.[55] Initially, these approaches sought to bring greater clarity and awareness of the 'un-priced' benefits that economies and society derive from natural systems. Over time, as the concepts of natural capital and ecosystem services have gained greater traction, focus has turned to the development of practices that integrate 'natural accounting' into business decision making. For example, the Natural Capital Protocol defines business natural capital accounting as "the process of systematically recording a business' natural capital impacts and dependencies, assets and liabilities in a consistent and comparable way."[56]

These methods are important contributors to the toolbox for valuing rivers' diverse benefits, including techniques that can translate river services into monetary and non-monetary values.

However, despite progress on methods, the influence of ecosystem service valuation on decisions has remained limited for a variety of reasons, including the complexity of translating science into policy and, no doubt, because some ecosystem services remain poorly understood or measured and so are not included in standard ecosystem service valuation models. These include some, such as sediment transport, that are among those that provide the greatest and most direct benefits to regional or national economies.

5. CULTURAL, SPIRITUAL, AND RECREATIONAL VALUES OF RIVERS

Drava, Sava, keep on flowing
Danube, do not lose your vigour...

Lines from the Croatian National Anthem

While this report emphasizes that diverse decision makers need to better understand the economic and financial values of rivers, rivers also support a range of values that are often difficult to monetize or integrate into benefit-cost analyses. Specific rivers feature prominently in their country's cultural identities and histories, such as the Mississippi in the United States, the Magdalena in Colombia, the Nile in Egypt and the Irrawaddy in Myanmar. The Yellow River is known as China's 'mother river', although that name is also sometimes applied to the Yangtze. Many rivers are considered sacred to various religions, such as the Ganges River and the River Jordan. Rivers are central to the spiritual and cultural identity of many indigenous groups.

Specific spiritual values can be restored or protected during planning for river management. For example, an environmental flow assessment for the upper Ganges developed specific flow recommendations for various sites along the river, including Bithoor, an important town for Hindu pilgrims. The town has a riverside temple dedicated to Brahma and the community expects that, each year, the river will inundate the lower portion of the temple, believed to represent the Ganges washing the feet of Brahma. Thus, for Bithoor, the recommendation included a flow level calibrated to inundate the lower portion of the temple, and indicated that the flow should be achieved at least once, even within a dry year.[57]

The recreational values of rivers are growing in importance. In addition to the considerable recreational value of freshwater fisheries (US$65-80 billion per year globally), rivers also provide value in the form of other recreational activities, such as canoeing, kayaking, rafting and wild swimming. While global, or even national estimates of total economic value are not available, paddling sports (rafting and kayaking) on the Colorado River alone are estimated at nearly US$180 million per year.[58] A 2006 study found that, in the United States, paddling sports were pursued by 24 million people, supported over 300,000 jobs and generated nearly US$5 billion in sales taxes.[59] Paddling sports are growing in importance in places such as Africa, Nepal, and the Balkan countries of Europe.

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3

VALUING RIVERS: MANAGING RIVERS FOR DIVERSE VALUES

Rivers provide a wealth of services that deliver significant economic and financial benefits to societies, yet river management rarely prioritizes these values, even as methods have improved to value them. So what has prevented decision makers from recognizing, and managing for, these crucial services?

A primary constraint on the ability of ecosystem service valuations to influence decisions arise from the complexity of translating science into policy. Posner et al. (2016) studied the impact of ecosystem service studies on policy and management and reported that the credibility of the science (e.g., studies developed by experts using rigorous methods) was not a significant predictor of whether the studies influenced policy. Rather, the "legitimacy of knowledge" was the most influential factor on impact, with legitimacy reflecting the processes through which the science was developed, with important factors including the incorporation of diverse perspectives and the co-production of knowledge with stakeholders.[60]

Thus, although rigorous science provides an important foundation for valuing rivers, translating those values into policy and management hinges more on collaboration, communication and coalitions. The remainder of this report focuses on a collaborative framework that ultimately strives to communicate rivers' values to influential audiences and build coalitions to translate value into action. Below we adapt a framework for valuing water[61] to review the components necessary for a new approach for valuing and managing rivers.

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3.1

MEASURE

In much of the world, minimal resources are available to monitor and measure the stocks and flows of water and this lack of basic information is one of the greatest challenges for sustainable water management.

Rivers' other values beyond water – such as sediment transport and fisheries – receive even less attention and, often, key processes and relationships are not even well understood. Simply increasing resources for measurement may not address these problems because measurement without a strong foundation of understanding can lead to a false sense of certainty. Since data are available, and often incorporated into models, decision makers can assume that the presence of data equates to understanding, but if key processes are not understood and measured, then those data may lead to incomplete, or even incorrect, conclusions. Thus, a programme to improve monitoring and measuring of river resources should be based on strong science to guide data collection and provide clear guidance on levels of confidence in the data, or associated modeling results.

Improving measurement and management of rivers' values through 4IR technologies

Water resources are often not measured effectively or comprehensively.[62] Global data on water balances, water quality, river flows, and other variables are often limited, with low resolution both in space and time. There are many reasons for this lack of data, but fundamentally, the near-universal low price of water has meant that it has often not been prioritized for measurement and this has cascaded down to a lack of monitoring in our rivers. Deficiencies in monitoring and measuring are even more common for the range of other river resources featured in this report.

Yet to maximize the value that rivers can offer us requires a fundamental change in the way we measure the resources in our rivers and river basins. Accelerating trends in technology have great potential to catalyze this change.

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The so-called 'Fourth Industrial Revolution' (or 4IR) offers a number of promising pathways to improve how we measure and manage environmental resources, including water. The 4IR is "characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres".[63] These technologies include artificial intelligence (AI), widespread mobile devices, digitization, unprecedented processing and storage capacity, remote sensing technology/data, the ability of devices to communicate directly with one another (also known as the internet of things or IoT), and digital ledgers allowing for verification (e.g., blockchain).

These technologies offer methods to measure rivers in ways that were nearly unthinkable even five years ago. The resulting opportunity to fundamentally re-think how we measure and track river values is immense. Indeed, for the first time, we may have reached the stage where limits are not defined by data availability but by the ability to process data and to effectively deploy and integrate new technologies. It is a dawn of a new era for measuring rivers.

This era begins with different technologies at different stages. For example, multispectral satellite data has been used to monitor water resources since the 1970s, meaning that we are quite well-versed on how to handle and deploy such technologies – even if the cost, resolution, volume and scope of such data have improved vastly.

Other technologies that have a fundamental ability to change how we value rivers, such as blockchain, are much more nascent. While it is not possible to be exhaustive in this section, a short review of a few of the more prominent technologies is helpful to understand how they are already enabling, or are positioned to enable, improved measurement of rivers and their values.

Cloud-based, AI-enabled processing of remotely sensed data/imagery is already underway and changing our ability to understand how river processes and resources shift through time and space. For example, our ability to track chlorophyll levels in rivers or algal blooms in lakes in near-real time represents a dramatic improvement from the past. Digitally-linked, IoT-enabled, in-stream flow meters and water quality sensors are another technology rapidly shifting how river resources can be measured. Similarly, mobile phones and tablets, linked to monitoring applications, now offer rural communities the opportunity to develop, compile and assess riverine measurements in near-real time. All of these technologies can provide rapid feedback and guidance for how we manage water resources.

Finally, while blockchain's applications to water remain largely under development, it is perhaps one of the most promising technologies for improving how river resources are tracked, measured, and valued. Blockchain, and its digital ledger, allows for 'digital verification' of data sources and performance. This verification could improve the utility of citizen science and the ability to crowdsource useful information. For example, through blockchain, it could be verified that citizen measurements of stream water quality came from a trained volunteer. Beyond monitoring, blockchain could also potentially enable water allocations to be traded dynamically with secure financial transactions. Beyond volumes of water, this could also apply to site performance (e.g., nutrient reduction of a wetland) or ecosystem service provision from a river, such as sediment transport. For example, the operators of a dam equipped to pass sediment could release sediment and have it digitally measured, via an internet-enabled remote device or perhaps satellite remote sensing, and verified in a digital ledger. Downstream beneficiaries (e.g., those that manage a delta) could track, in near-real time, and compensate the dam operator for the value of sediment with minimal transaction costs.

The sweeping changes in how we collect and process data can dramatically improve how we value and manage water resources. We should not miss this opportunity to leverage the breakthroughs arising from 4IR to also transform how we measure, value and manage rivers and their diverse resources.

VALUE

Water is arguably the most precious resource on Earth, and yet we often value and manage it extremely poorly. The price of water traditionally reflects a limited set of costs to treat and transport water, but the value of water is far greater. Low and subsidized water prices are important to ensure access and equity, but water's low market-based cost has resulted in profligate use, freshwater contamination and, in general, has contributed to the loss and decline of many river resources (Box 2).

Further, rivers' 'hidden' services can be even more difficult to value. Various methods have been developed, or are emerging, to improve valuation of water and rivers' services. While quantifying value is an important step, we believe that how and to who rivers' values are communicated are as, if not more, important than the quantification of value.

To influence decision makers, rivers' values cannot be siloed as 'environmental' resources that are only relevant to ministries that manage water and the environment. Rather, they must be framed in terms that are relevant to ministries and planners responsible for economic growth and investment, as well as to important sectors of the economy.

Rivers in the Economy: valuing and communicating rivers' diverse benefits

WWF has developed an approach called 'Rivers in the Economy' (RitE) that attempts to capture the paradigm shift of valuing rivers for a broader set of values. The RitE process tries to highlight the range of values delivered by healthy rivers and to communicate these to stakeholders and decision makers in the language they use and through examples and trends that resonate with them. The aim of a RitE process is to help decision makers and stakeholders identify and then understand how rivers' diverse – and often hidden – values support their own interests. The process may also include identification of sustainable development pathways or scenarios that achieve economic growth objectives without undermining those values.

In several countries or regions, WWF has undertaken the RitE approach in an effort to drive policy changes by recruiting a set of advocates for improved management – advocates that are far more diverse than those who typically promote environmental protection. These advocates should be engaged throughout the process, so a successful RitE effort requires the team to identify the key decisions they would like to influence and then recruit the relevant stakeholders and decision makers to take part in the process (Figure 6). Through this engagement – from recruitment to sustained engagement – it is the process itself, more than the documents produced, that is most impactful in terms of building diverse coalitions, which can support sustainable river management.

Table 1. *WWF's Water in the Economy and River in the Economy processes to date*

Year	Country	River Basin
2008	Kenya	Lake Naivasha
2010	Zambia	Kafue Flats
2012	Suriname	National
2012	Turkey	Lake Sapanca
2015	Vietnam, Cambodia, Laos, Thailand	Lower Mekong
2016	India, Nepal, Bhutan	Living Himalayas
2017	Mexico, USA	Rio Grande-Rio Bravo
2018	Croatia, Montenegro, Bosnia and Herzegovina	Neretva & Trebisnijica
2018	Kenya, Tanzania	Mau-Mara
2018	Myanmar	Irrawaddy

WWF has conducted RitE processes for several freshwater systems over the past decade (Table 1), beginning with Lake Naivasha in Kenya in 2008 through to current efforts on the Irrawaddy River in Myanmar.

As described above, the RitE process is intended to reach an audience broader than typical water and environmental managers, and generate information that resonates with financial and economic planners and important sectors in the economy.

- *WWF's first RitE process.* The Lake Naivasha area, the most important producer of flowers in Kenya, was facing declining water quantity and quality from the rivers that feed the lake. By reframing a local water resources management challenge in terms of a significant economic issue (export of flowers represents 10 percent of Kenya's foreign exchange), the issue was escalated to the Prime Minister's Office. In response, the Imarisha Naivasha Initiative was started to develop a Sustainable Development Action Plan and funnel funding to improve water security for both the environment and the economy in the region.
- *Understanding the risks of fragmentation in the Mekong to build stewardship opportunities.* The Mekong RitE process engaged diverse stakeholders from across the region and highlighted three levels of fragmentation that exacerbated water management challenges: (1) geographic fragmentation among countries developing for individual benefit and not regional gain; (2) sectoral fragmentation where sector development plans are not aligned; and (3) temporal fragmentation due to poor consideration of short, medium and long term impacts of development in the basin. Furthermore, it was the physical fragmentation of the basin, such as dams that blocked flows of fish and sediment, that were the biggest water management challenge, not volumes of water per se. The process also revealed that the region was developing in such a way that gains for one sector, such as energy, were coming at the expense of others, such as food security – an important message for the diverse stakeholders engaged in the process.
- *"Streams" of income and jobs in the Neretva and Trebisnjica River Basins.* This RitE process helped to highlight the lack of comprehensive understanding of the value and interdependence of shared water resources among Croatia, Montenegro, and Bosnia and Herzegovina. While this problem was widely known, the four jurisdictions covered in this study are continuing to make separate water management decisions, which can, and do, negatively affect both their own and each other's communities and economies as well as the environment. By highlighting this in terms of income and jobs, important factors driving decisions in the region, it is hoped that the diverse value of the river will be better understood, prioritized, and managed for.

THE RITE APPROACH

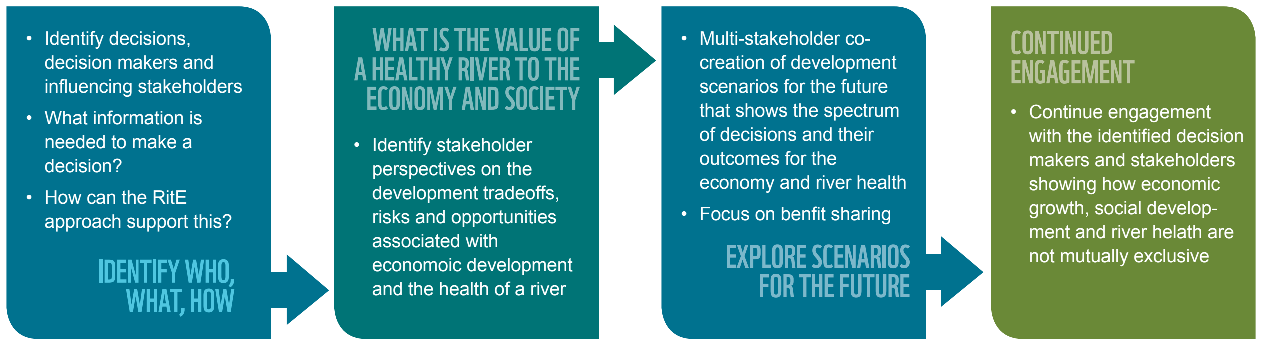

Figure 6: *Key components of a River in the Economy process*

Ultimately, the RitE approach promotes sustainable river management by recruiting diverse advocates and building coalitions to support the necessary policy and management changes – advocates and coalitions who are motivated by recognition of how they directly benefit from healthy rivers. To be successful, RitE processes must engage these stakeholders and decision makers from the start, to ensure that the information generated will be relevant to, and understood by, those key groups and thus more likely to be implemented. Beyond its results, the process itself, featuring consistent dialogue and collective learning, promotes a shared understanding of the diverse values of healthy rivers and provides a foundation for collaborative implementation.

Improving communication of value and risk through data, mapping and analysis: the Water Risk Filter

For decision makers to value rivers more broadly – and to act on that value – requires that data be converted into useful information about those values. For the past decade, WWF has used a narrative about water risk to engage companies about why water matters to their operations and supply chains. Central to this work has been a unique tool developed by WWF and DEG-KfW, the Water Risk Filter (WRF; see Box 6).

The WRF is an easily accessible, online tool, which allows users to explore, assess, value and respond to basin and operational water risks. Although companies often think about water risk in a literal, operational way – meaning risk of water as a defined commodity – the WRF encompasses a much broader set of risks around water, including ecosystem degradation, reputational and regulatory risks. In this way, the WRF can be used to support the fact that rivers provide a set of important values that go beyond just the provision of water as a commodity and thus decision makers need to understand the benefits, and risks, associated with these diverse river values.

The risk narrative has largely been directed towards companies so far and they have been the primary users of the WRF. However, the risks associated with poor management of water systems, including rivers, can also affect whole economies. Indeed, we can use the WRF to investigate where economic activity may be most at risk from poor management of water and develop results and maps that can communicate the values of rivers and the benefits of sustainable water management. In Figure 7 we overlay global water risk with a geographically distributed measure of Gross Domestic Product (i.e., national GDP that is spatially distributed based on location of population and economic activity) to illustrate the intersection of water risk and economic activity. The result is a preliminary assessment of where ineffective management of water resources, including rivers, could lead most directly to economic impacts. For example, nearly a quarter of GDP in Asia lies within watersheds with high to very high water risk, as does 20 percent of GDP in Africa. Overall, 19 percent of global GDP comes from watersheds with high to very high water risk.

Such water risk maps can be linked to other material economic statistics that matter to governments, such as jobs, growth, unemployment and migration. Indeed, risk is only part of the story. Where there is water risk hampering the economy, there also exists the opportunity to unleash growth by restoring rivers and water resources and reinvigorating the economy.

In short, combining water risk and economic data offers a lens to help identify both threats and opportunities to catalyze improved management of rivers and their values.

6. THE WATER RISK FILTER

The Water Risk Filter is a leading, online tool developed by WWF and DEG that can assess, analyze, and value water risks and guide appropriate responses.

The WRF is the only water risk tool to assess both basin and operational water risk (e.g., for a facility). The tool uses over 30 annually updated, peer reviewed river basin data layers along with a site-based questionnaire to score and help identify and prioritize water risk for users.

Re-launched in 2018, version 5.0 offers over 130 actions to respond to water risks, including adaptation actions for water-related climate impacts, making it an even more useful tool for sites anticipating future changes in water resources. It also contains a new section on valuing water risk, and valuing rivers, allowing users to explore economic value by river basin. Furthermore, the newest version also offers higher resolution data for 12 new countries (over 12 million km^2 of total area).

Online since 2012, the tool is a trusted source of water risk data used by thousands of individuals and companies to evaluate hundreds of thousands of sites. To explore the tool, please go to: **waterriskfilter.panda.org**

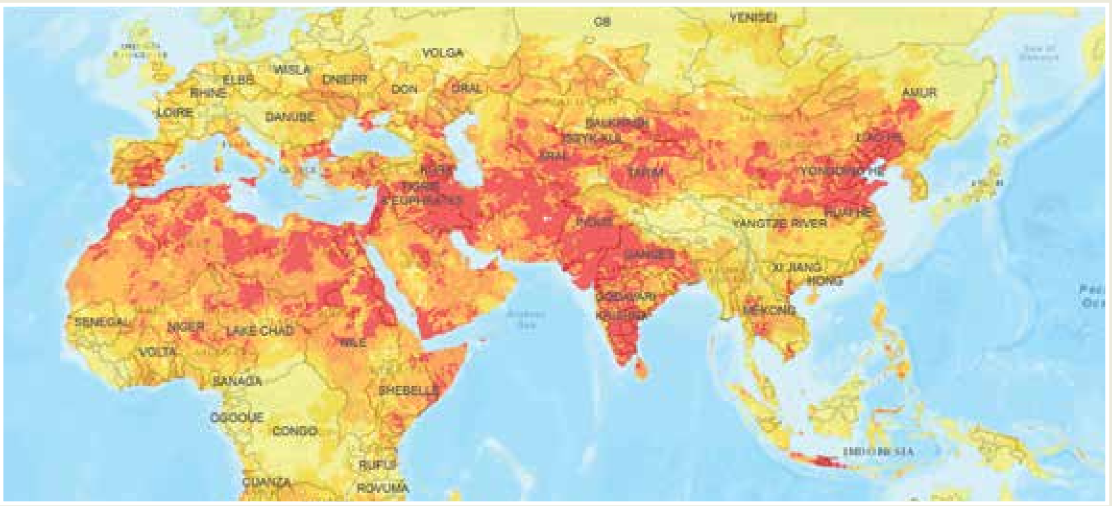


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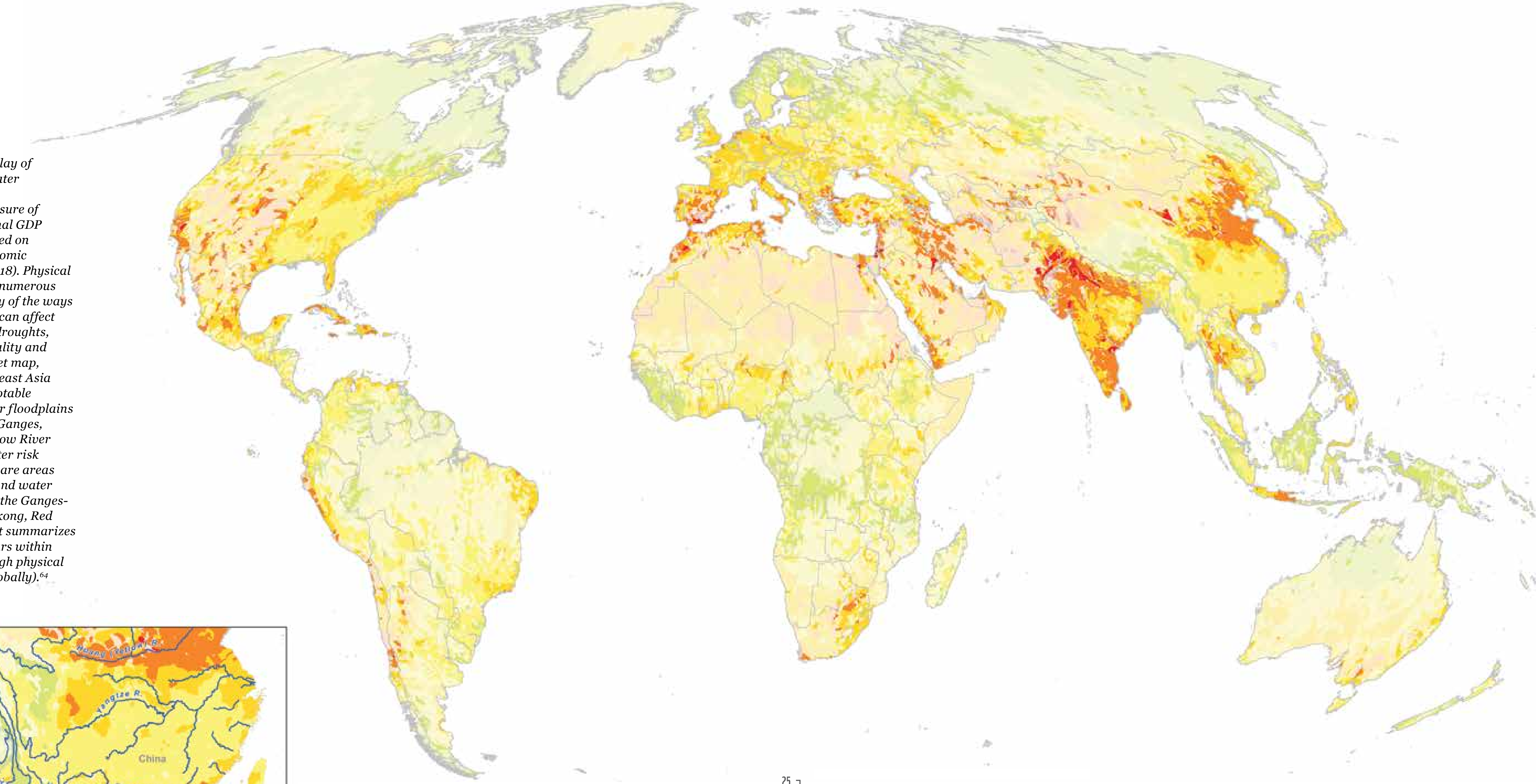
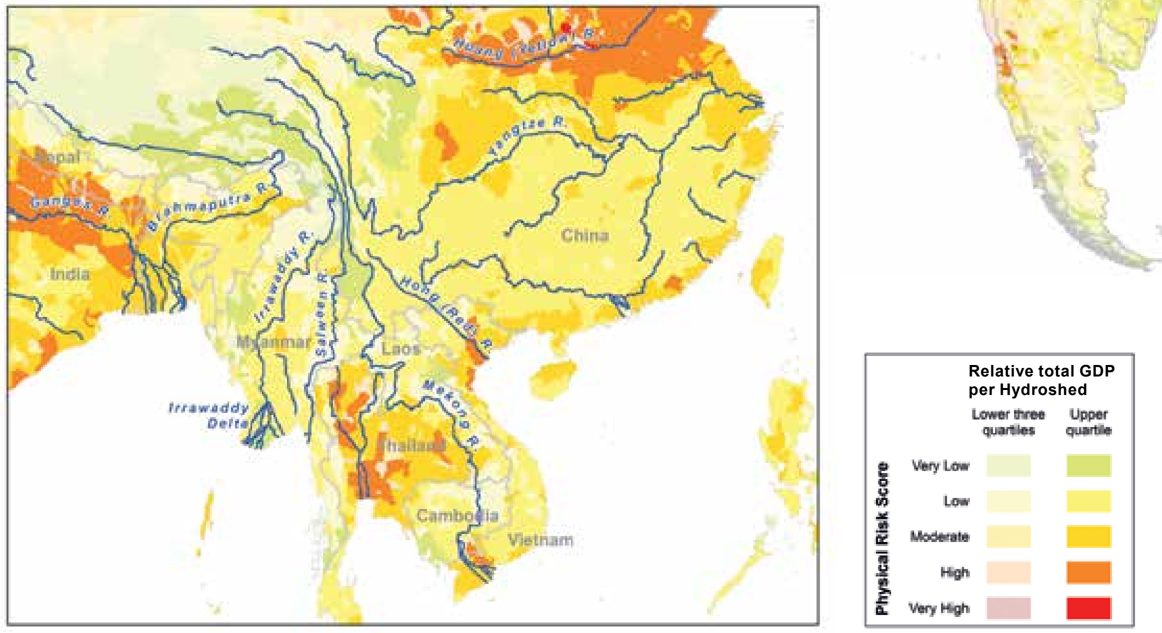
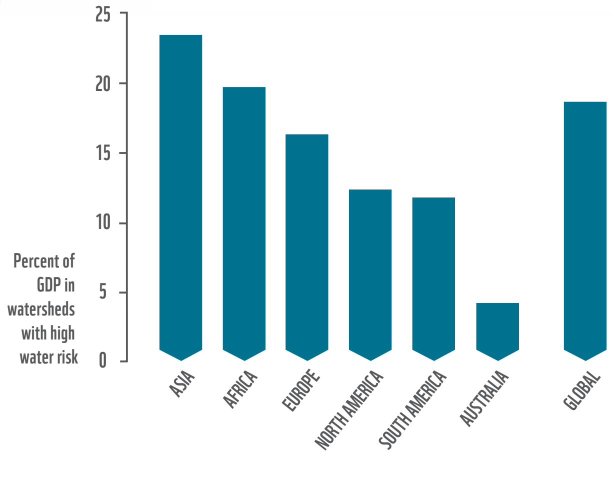
Figure 7: *GDP and water risk. The global map depicts the overlay of physical water risk from the Water Risk Filter (WRF, 2018) with a geographically distributed measure of Gross Domestic Product (national GDP that is spatially distributed based on location of population and economic activity) from Kummu et al. (2018). Physical water risk in the WRF includes numerous indicators that encompass many of the ways that the hidden values of rivers can affect economies, including scarcity, droughts, floods, and threats to water quality and freshwater ecosystems. The inset map, focused on eastern India, Southeast Asia and China, highlights several notable patterns. For example, the lower floodplains of major rivers – including the Ganges, Chao Praya (Thailand) and Yellow River – frequently have both high water risk and high GDP. Similarly, deltas are areas of concentration for both GDP and water risk, illustrated by the deltas of the Ganges-Brahmaputra, Chao Praya, Mekong, Red and Yellow rivers. The bar chart summarizes the proportion of GDP that occurs within watersheds with high to very high physical water risk (by continent and globally).*[64]







19 PERCENT OF GLOBAL GDP COMES FROM WATERSHEDS WITH HIGH TO VERY HIGH WATER RISK

UNDERSTAND TRADEOFFS

Even with improved measurement and valuation of resources, decision making about river management will require navigating difficult tradeoffs. Decision science has recently produced new approaches to integrate a more diverse set of values into planning, management and policy decisions. In this section we examine how multi-objective tradeoff analysis can help decision makers visualize and understand tradeoffs, often across market and non-market values, to guide planning and management. The specific example in this section focuses on hydropower, but this approach to understanding tradeoffs can be applied to nearly all aspects of river management.

TRADEOFF ANALYSIS TO UNDERSTAND AND MANAGE MULTIPLE DIMENSIONS OF RISK

Dams are expanding in the later-developing world, including the rapid development of hydropower dams to meet growing demands for energy (Figure 1).[65] Although this expansion in water-management infrastructure can meet important societal needs, a proliferation of new dams threatens to greatly diminish the ecological health of rivers in regions where rivers support high levels of biodiversity and provide livelihoods and food security to millions of rural people.[66] Opperman et al. (2015) found that the projected hydropower development by 2050 could fragment rivers or alter flows, or both, on 300,000 kilometres of river channel worldwide.[67]

In addition to electricity, hydropower projects often perform multiple purposes, including water supplies for drinking and/or irrigation and flood-risk management. Thus, hydropower projects are major infrastructure investments that can provide water and energy benefits to support development goals and economic activity but they can also cause significant environmental and economic impacts. Decision making for hydropower requires a clear understanding of these risks: environmental, social, economic and financial.

Below we describe these risks and then discuss how an understanding of tradeoffs, through a system planning approach, can identify options for hydropower development and management that minimize risks and provide more balanced outcomes across river resources.

Environmental and social risks

Rivers and associated ecosystems are among the most diverse and productive ecosystems on Earth, producing the greatest per area value of ecosystem services.[68] Furthermore, river valleys often support high value agricultural land as well as towns and cities. The dams required to generate hydropower necessarily change rivers and river valleys and thus, in addition to creating development benefits, hydropower can cause significant social and environmental impacts, including the loss of migratory fish, inundation of cropland and displacement of people.

Economic risks

The loss of fisheries and other ecosystem services represents economic losses, although these can often be difficult to quantify or, if quantified, can remain relatively distant from what drives development decisions.

The most direct economic risk associated with poorly planned hydropower involves the opportunity cost of poor investment choices: in the absence of strategic planning, major infrastructure investments, such as dams, can fall short of their potential to work together to deliver the broadest development benefits and, in fact, may even interfere with each other, compromising the performance of individual investments.

At a broad scale, hydropower projects are major investments that potentially provide services not just for energy but also for water management, including water supply, irrigation, navigation, and flood-risk reduction. However, in the absence of strategic system planning, hydropower investments may not fulfill their potential to provide these services.

Financial risks

The economic, environmental and social impacts described above can contribute to conflicts that delay hydropower projects and cause cost overruns. Conflicts can even lead to cancellations, as demonstrated by a number of high-profile project cancellations in the past decade, including Myitsone in Myanmar (6 GW; suspended after US$800 million had been invested), HidroAysén in Chile (2.75 GW; US$320 million invested) and São Luiz do Tapajós in Brazil (8 GW, US$150 million invested).[69]

Beyond these high-profile examples, hydropower projects have been reported as having greater schedule delays and cost overruns than other large infrastructure projects.[70] From these studies, it is not clear the extent to which environmental and social issues contributed to the delays and cost overruns, because hydropower projects are very site-specific with high upfront capital costs, leading to a range of risks and uncertainties, including currency fluctuations, geotechnical problems, and labour. However, the combination of high capital cost and complexity with the fact that hydropower projects, particularly large ones, often significantly impact communities and ecosystems does suggest that environmental and social issues are contributing to the common challenges confronted by the hydropower process – and thus that better management of environmental and social issues would help hydropower from an investment perspective (lowering risk, increasing flows of investment) and not just from the perspective of meeting sustainability aspirations.

In fact, a recent review of hydropower stated that the "significant increase in hydropower capacity over the last 10 years is anticipated in many scenarios to continue in the near term (2020) and medium term (2030), *with various environmental and social concerns representing perhaps the largest challenges to continued deployment if not carefully managed.*"[71]

A lack of system planning and management in hydropower creates multiple problems – not just greater environmental and social impacts but also conflict, delays and cancellations leading to investment risk and the risk to countries that major investments do not contribute effectively to national energy and water needs. For these reasons – spanning fisheries to rural development needs to national climate goals – the hydropower sector should strive to adopt improved processes for planning and management, which can address shortcomings and maximize strategic values.

System planning and tradeoff analysis to understand and manage risk

A range of studies and real-world examples have demonstrated that many of the challenges described above can be best addressed through planning and management at the system scale. These include assessment of the potential for maintaining or restoring free-flowing rivers and connectivity while maintaining energy generation.[72] A system planning process for hydropower was implemented in Norway in the 1980s, reducing conflict and increasing certainty for both the hydropower sector and conservationists.[73] Finally, numerous studies demonstrate that countries can secure broader economic gains through system-scale planning and management of water-management infrastructure than through a set of single-project decisions.[74]

In essence, system planning for hydropower is a set of principles intended to facilitate balanced outcomes across economic, environmental and social values during hydropower development and management. The application of these principles results in a process for collecting and analyzing data to compare how different options (with an option defined as a specific combination of project locations, designs and operations) perform across a range of resources and values that have meaning for stakeholders with results intended to inform decisions about investments and management.

Comparing these different options can be done through a multi-objective analysis of tradeoffs. Output from the analyses can be used to identify a set of options that are likely to perform well across a range of metrics. However, tradeoffs are often unavoidable and model outputs can also be used to quantify those tradeoffs. Clear visualizations of results are important to ensure that decision makers and stakeholders understand the opportunities and tradeoffs and thus the implications of selecting various options. Figure 8 provides an example of a visualization of results that can illustrate tradeoffs and help users identify potentially well-balanced options.

WWF and partners are now pursuing system-scale approaches to energy planning and river conservation in regions such as the Irrawaddy Basin (Myanmar), the Himalayan rivers of Nepal, the Amazon and the Balkan region of southeast Europe. While tradeoff analysis can identify promising options for development or management, implementing those options will require governance mechanisms. In the next section we explore various governance mechanisms, including those that can implement the results of system planning for hydropower (see Box 7).

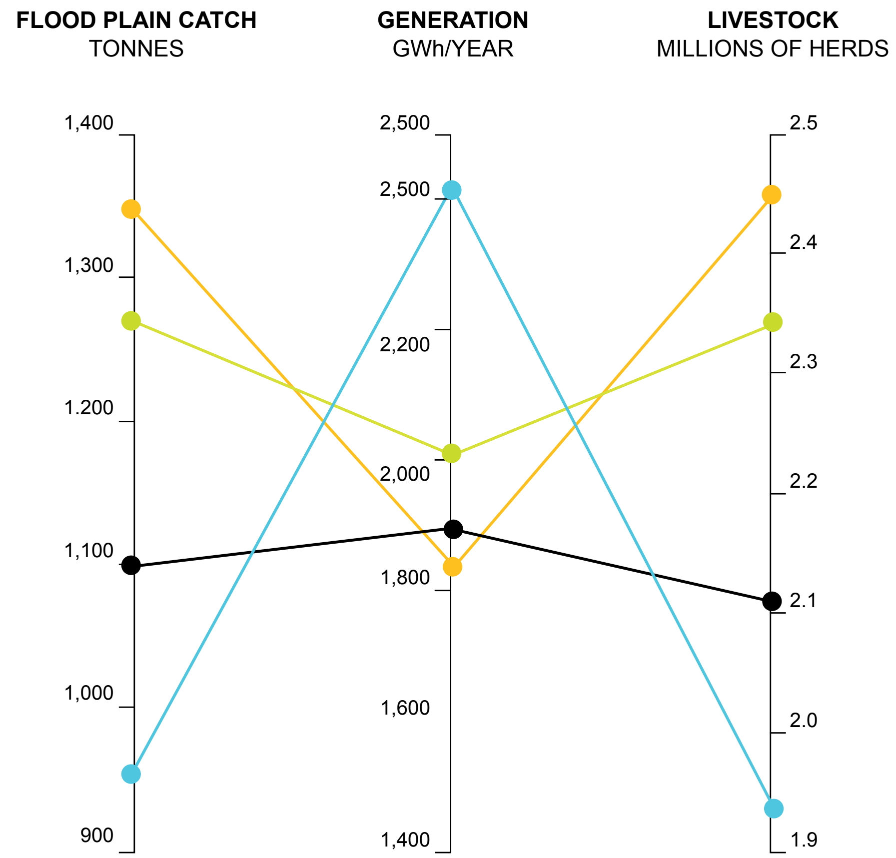


Figure 8: *Comparison of four different options (different coloured lines) formanaging a cascade of dams on the Tana River, Kenya in terms of how each option performs across three metrics: harvest of floodplain fish (floodplain catch), generation of electricity, and the ability of floodplain grasslands to support livestock. Performance is indicated by where a line representing an option crosses the axis for that metric, with better performance at the top of the line. This figure can illustrate tradeoffs (e.g., the option that maximizes generation (blue line) will result in the lowest performance for fish and livestock) as well as identify options that perform well across multiple metrics. For example, the option represented by the green line does not score highest for any metric but has the second best performance for all three metrics, suggesting an outcome that may produce a broader range of benefits and a better balance among traditional uses (generation) and rivers' 'hidden' values (floodplain productivity). From Opperman et al. (2017) used with permission from The Nature Conservancy.[75] Data for the figure are from Anthony Hurford and Julien Harou (University of Manchester) from a project supported by colleagues from the International Water Management Institute (IWMI), ODI, BC3 and ACCESS, under the IUCN-led WISE-UP to Climate Project. WISE-UP to Climate is funded by the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).*

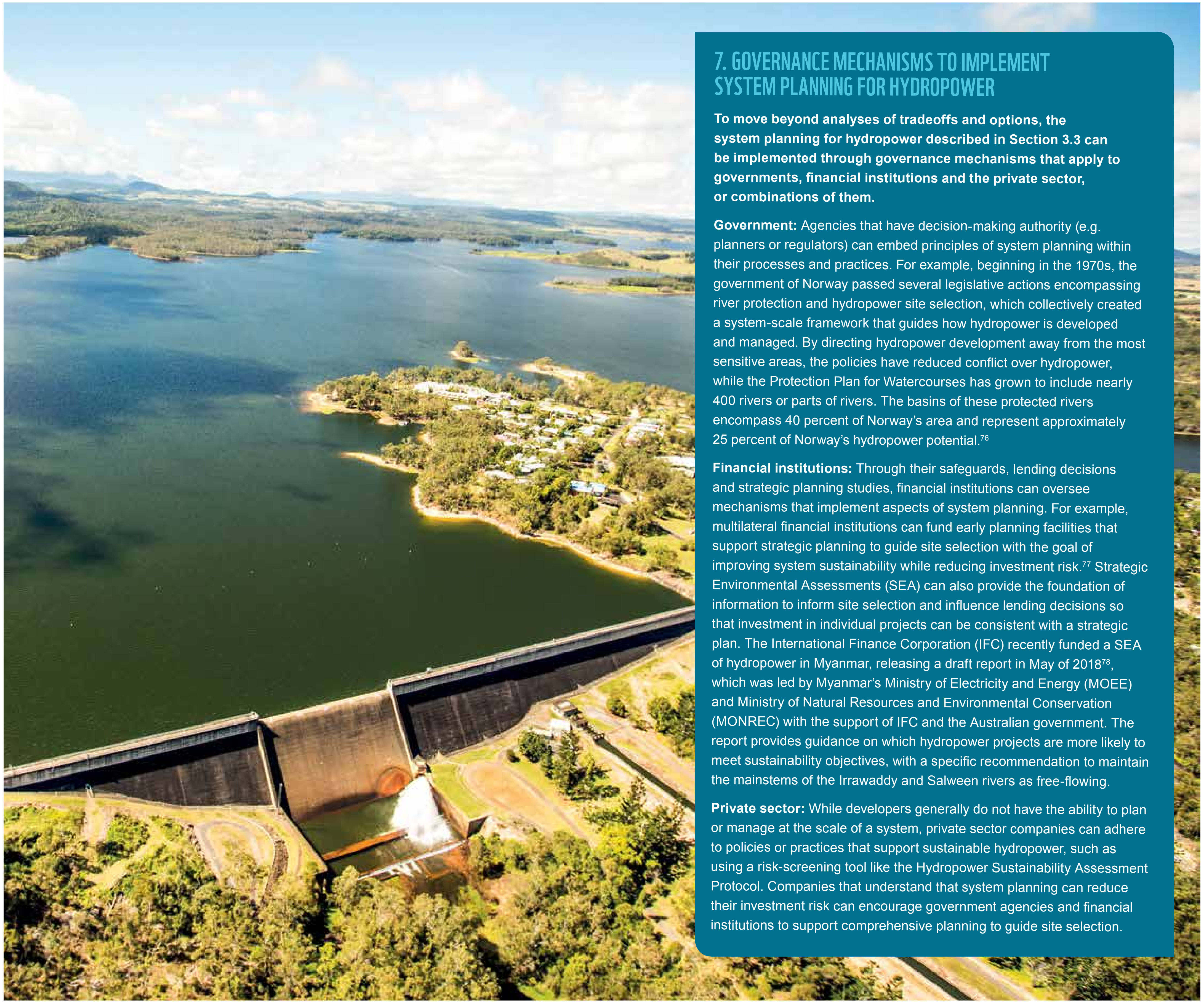
IMPROVE GOVERNANCE

Implementing decisions and ensuring that progress is durable requires effective water-management institutions and governance. In this section we examine governance mechanisms that include formal government (policies, planning and regulation) but also include financial policies and mechanisms to incentivize sustainable investment decisions as well as private sector policies and practices.

Allocation

Valuing rivers involves difficult tradeoffs about who gets water, and how much. In other words, valuing rivers is a process of allocating water – ranking competing water uses relative to one another. This process is intensely political; in almost all cases, rivers have been developed and allocated before the wider benefits of rivers were fully recognised and integrated into planning and allocation decisions. Any effort to value rivers must confront this reality by strengthening institutions and governance to address the twin challenges of creating incentives and dealing with vested interests.[79] The impacts of water shortages, and the increasing recognition of the link between river health and sustainable water resources, create opportunities to address these challenges.

Several tools and approaches have been adopted over previous decades. Notably, allocation has occurred through communities, governments, markets and varying blends of the three.[80] Common to all approaches are efforts to draw a line between the water that can be consumed, and the water that must be conserved for rivers to function and thrive. Sixty years after the first efforts to designate minimum flows in the tributaries of the US Pacific Northwest, the field of environmental flows and environmental water is now mature, and increasingly integrated into water planning and allocation. Despite breakthroughs around the world – from flood pulses delivered across international borders to the Colorado River Delta to national programmes in Mexico (Box 8) to South Africa – examples of large-scale, sustainable water allocation remain elusive.[81]



7. GOVERNANCE MECHANISMS TO IMPLEMENT SYSTEM PLANNING FOR HYDROPOWER

To move beyond analyses of tradeoffs and options, the system planning for hydropower described in Section 3.3 can be implemented through governance mechanisms that apply to governments, financial institutions and the private sector, or combinations of them.

Government: Agencies that have decision-making authority (e.g. planners or regulators) can embed principles of system planning within their processes and practices. For example, beginning in the 1970s, the government of Norway passed several legislative actions encompassing river protection and hydropower site selection, which collectively created a system-scale framework that guides how hydropower is developed and managed. By directing hydropower development away from the most sensitive areas, the policies have reduced conflict over hydropower, while the Protection Plan for Watercourses has grown to include nearly 400 rivers or parts of rivers. The basins of these protected rivers encompass 40 percent of Norway's area and represent approximately 25 percent of Norway's hydropower potential.[76]

Financial institutions: Through their safeguards, lending decisions and strategic planning studies, financial institutions can oversee mechanisms that implement aspects of system planning. For example, multilateral financial institutions can fund early planning facilities that support strategic planning to guide site selection with the goal of improving system sustainability while reducing investment risk.[77] Strategic Environmental Assessments (SEA) can also provide the foundation of information to inform site selection and influence lending decisions so that investment in individual projects can be consistent with a strategic plan. The International Finance Corporation (IFC) recently funded a SEA of hydropower in Myanmar, releasing a draft report in May of 2018[78], which was led by Myanmar's Ministry of Electricity and Energy (MOEE) and Ministry of Natural Resources and Environmental Conservation (MONREC) with the support of IFC and the Australian government. The report provides guidance on which hydropower projects are more likely to meet sustainability objectives, with a specific recommendation to maintain the mainstems of the Irrawaddy and Salween rivers as free-flowing.

Private sector: While developers generally do not have the ability to plan or manage at the scale of a system, private sector companies can adhere to policies or practices that support sustainable hydropower, such as using a risk-screening tool like the Hydropower Sustainability Assessment Protocol. Companies that understand that system planning can reduce their investment risk can encourage government agencies and financial institutions to support comprehensive planning to guide site selection.

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Why is it difficult to value rivers in water allocation decisions? Firstly, the benefits from rivers are distributed broadly across populations, and there is limited incentive for individuals and communities to do their part to sustain and prioritise these values when there are more immediate opportunities to develop and use the resources. Many public goods are sourced or supported by rivers, such as the environmental services provided by wetlands and floodplains to enhance flood control and water quality. These values are hard to incorporate into allocation decisions because they benefit everyone regardless of relative contributions to their conservation. This causes an incentive problem, tempting individuals, communities and governments to free ride on the investments of others. Efforts to integrate these broader values of rivers into allocation decisions require the cultivation of capacity, political will and financing.[82] This ensures individuals and organizations are equipped to come to the table for allocation, and have the technical skill and political influence to persuade other stakeholders that it is in everyone's best interest to both give to, and benefit from, rivers.

Secondly, while benefits are distributed broadly and deferred, costs are often localised and immediate.[83] In short, existing water users – often in agricultural, resource-scarce, or rural communities – stand to lose out when society decides to elevate the value of rivers in allocation decisions. These social dimensions of water allocation and reallocation have often been ignored, or underestimated, in policy recommendations. Valuing rivers in water allocation requires tackling these fundamental barriers head-on, and entering into a broader discussion of rural futures and resource equity. By shifting from a narrow perspective of allocating water to sharing benefits, it is possible to change from a zero-sum game to a focus on shared prosperity.

These challenges are surmountable. Multiple values require multiple tools, blending effective policies, incentives and partnerships. Effective allocation policies hinge on recognising the diverse values from rivers – particularly the 'hidden' values – as legitimate and legally sanctioned uses of water.[84] Legal recognition of the value of rivers can include statutes or regulations that establish specific values as 'beneficial uses' or otherwise legally acceptable uses. In the Western USA, efforts to restore instream flows in water-stressed river basins have involved a multi-decade effort to achieve such recognition, which has subsequently opened up incentive-based tools, such as leasing and mitigation banks.[85] Globally, the recent push to recognise the value of rivers has culminated in legal rights for rivers in regions as diverse as Colombia, India and New Zealand.[86] The widespread implementation of Environmental Water Reserves, which protect flows, in Mexico was made possible by legislation that recognized diverse values from rivers (Box 8). Harwood et al. (2018) found that "conducive legislation and regulation" was the "fundamental enabling factor" for implementation of environmental flows.[87]

These policy and legal trends reflect growing recognition of the value of rivers. But recognition is not sufficient on its own. Legal recognition must go hand in hand with capacity and commitment by individuals and groups to represent these values in technical, planning and policy initiatives. In the Colorado River, environmental organisations have developed advanced analytical capacities with river system models to integrate the value of rivers into planning and operational scenarios.[88] Such efforts are not restricted to the wealthiest countries. Citizen science and actions from Tanzania to Myanmar are developing the tools for valuing rivers and integrating those values into allocation decisions.

Scalability and implementation depend on political will, financing and the underpinning cultural imperative. They also require linking incentives with policy change. Incentive-based tools range from market transactions to reallocating water for environmental purposes. Efforts in Australia, the USA and Spain illustrate that such tools can play an important role, but they are the servant of sound governance, not the master.[89]

In short, market-based tools depend on all four steps for valuing rivers: measurement, valuation, tradeoffs and governance. Specifically, market-based tools require effective water accounting to ensure reallocation projects deliver a net increase in water to support neglected values. Water balances and budgets can determine whether the historic water user groups reduce consumption and free up water to support environmental flows, including a diverse range of benefits: sediment transport, wetland restoration (including flood risk reduction) and more traditional environmental goals linked to habitat restoration. These benefits can be estimated and quantified via processes that link economic and cultural approaches to overcome the disadvantages of relying on either one by itself. In parts of northern Scotland, for example, participatory approaches to valuation complemented monetary valuation techniques and built stronger support for planning and allocation decisions to conserve coastal wetlands.[90]

Finally, new policies and incentives are fostering innovative models of collective action, particularly bridging divides between the public and private sectors and across scales. Valuing rivers requires that the diverse interests supported by functioning rivers have proper forums to identify their common interest and negotiate allocation decisions that balance benefits for specific groups with the benefits for the river and the system more broadly.

These new models of collective action involve public-private partnerships such as stewardship initiatives that facilitate watershed planning and allocation beyond the fenceline (see following section on Context-based Water Targets). They also require partnerships across scales. The importance of catchment and basin initiatives has long been recognized but they are often difficult to implement in practice due to the tradeoffs between sectors and scales sharing a basin. Success has involved blending the policies, incentives and capacity building to realise the potential for benefit sharing even when specific sectors, such as agriculture, may need to reduce water consumption. Examples include central Mexico and Brazil where regional initiatives link allocation processes with system planning and modelling efforts to support novel partnerships.

Both of these examples highlight the growing importance of urban-rural partnerships to overcome some of the barriers affecting basin-wide initiatives. The economic growth and resource constraints faced by cities are creating a driver for collective action with rural regions, including agricultural and extractive industries that are negatively affected when growth is unplanned. These partnerships create openings for the broader value of rivers to be considered in planning and allocation decisions. Box 9 provides 10 'golden rules' of sustainable water allocation planning.

8. ENVIRONMENTAL WATER RESERVES IN MEXICO

In 2005, the Gonzalo Río Arronte Foundation (FGRA) and WWF-Mexico formed an alliance to explore new models for water management that would integrate the protection of environmental flows within decisions for water allocation (e.g., for drinking water, irrigation or hydropower). Pilot studies were conducted in three basins (including Rio Conchos: see photo) and, subsequently, FGRA-WWF proposed to Mexico's National Commission on Water (CONAGUA) a standard for determining environmental flows within water allocation processes.[91]

Rather than requiring a specific method to designate flow levels, the environmental flow standard emphasized a set of scientific principles intended to maintain a balance between flow protection and water use. The balance between these objectives is set along a continuum determined by the value of a river's environmental resources and the level of demand for water in the river basin.[92] The Mexican environmental flow standard was published in 2012 and ratified in 2017.[93]

To translate environmental flow determinations into water allocation decisions that would protect flows over the long term, FGRA-WWF joined with CONAGUA and the National Commission of Natural Protected Areas (CONANP) to launch a National Water Reserves Program (NWRP). Building on the legal concept of a "water reserve" – a set volume of water dedicated to a specific use such as irrigation – the Program established an "environmental water reserve" (EWR), defined as a volume of water that must remain in the river to support environmental values and cannot be allocated for other purposes.

In September 2014, the first EWR was formally established for 11 sub-basins within the San Pedro-Mezquital Basin. Demonstrating that the EWR can influence decisions about water allocation and water infrastructure, the environmental review process for a hydropower dam on the San Pedro was halted because it would not have been able to be operated in a manner consistent with the EWR.[94]

The Government of Mexico is now pursuing one of the largest programmes in the world to integrate environmental flow protections within water allocation. In June 2018, Mexico's President Enrique Peña Nieto signed a series of decrees establishing EWRs in nearly 300 river basins. The decrees will guarantee water supplies for the next 50 years for 45 million people, while protecting globally important wetlands and Mexico's last free-flowing rivers. Among these rivers is the Usumacinta, which is the largest and most biodiverse river in Central America and is now covered by an EWR that protects 93 percent of its water.

The EWR approach illustrates how valuing rivers for diverse benefits can be integrated into governance mechanisms for water allocation. WWF is now proposing the Environmental Water Reserve concept as a model for other countries in Latin America, such as Bolivia, Colombia, Ecuador, Guatemala and Peru.[95]

THE APPROACH ILLUSTRATES HOW VALUING RIVERS FOR DIVERSE BENEFITS CAN BE INTEGRATED INTO GOVERNANCE MECHANISMS FOR WATER ALLOCATION.

9. TEN GOLDEN RULES OF WATER ALLOCATION PLANNING

1. In basins where water is becoming stressed, it is important to link allocation planning to broader social, environmental and economic development planning. Where inter-basin transfers are proposed, allocation planning also needs to link to plans related to that development.
2. Successful basin allocation processes depend on the existence of adequate institutional capacity.
3. The degree of complexity in an allocation plan should reflect the complexity and challenges in the basin.
4. Considerable care is required in defining the amount of water available for allocation. Once water has been (over) allocated, it is economically, financially, socially and politically difficult to reduce allocations.
5. Environmental water needs provide a foundation on which basin allocation planning should be built.
6. The water needs of certain priority purposes should be met before water is allocated among other users. This can include social, environmental and strategic priorities.
7. In stressed basins, water efficiency assessments and objectives should be developed within or alongside the allocation plan. In water-scarce situations, allocations should be based on an understanding of the relative efficiency of different water users.
8. Allocation plans need to have a clear and equitable approach for addressing variability between years and seasons.
9. Allocation plans need to incorporate flexibility in recognition of uncertainty over the medium to long term in respect of changing climate and economic and social circumstances.
10. A clear process is required for converting regional water shares into local and individual water entitlements, and for clearly defining annual allocations.

Excerpted from Speed et al. 2013.[96]

Context-based water targets

Private sector companies are increasingly understanding the importance of water to their financial performance and, in response, are integrating water stewardship into their practices (e.g., Nestle Waters' certification under the Alliance for Water Stewardship standard; Box 10). While much corporate water stewardship activity to date has focused on site-specific interventions (e.g., water use efficiency or pollution reduction), stewardship commitments and activities also represent a form of water governance.

Experience to date suggests that site-specific actions often fail to achieve broader benefits when they are developed and implemented without consideration of the site's context – the biophysical and social conditions within the river basin and the interactions that flow both up- and downstream. For example, water use efficiency targets should be adjusted to account for the relative scarcity of water in a basin; limits on diversions from a river should be informed by environmental flow needs of the ecosystems and users downstream.

To address the limitations of site-focused targets, a group of companies and stakeholders are exploring the concept of context-based water targets (CBWT). The objective of placing stewardship activities within a broader context of resources, impacts, and opportunities echoes the major theme of this report – the need to move beyond the valuing of water as a bulk commodity and towards valuing rivers as systems that interact with natural and human systems to produce diverse benefits.

CBWTs strive to link water use and stewardship at a site to its basin context, including shaping targets so that they contribute both meaningfully and proportionally to the protection of river values. More specifically, CBWTs are specific time-bounded targets that consider a site's water performance (e.g., aqueous emissions, water consumption, etc.) based on a site's proportionate responsibility to contribute to a sustainable river system (Figure 9). They explicitly account for rivers by considering environmental flow needs as well as other ecosystem service needs in the basin, along with basic social needs (Figure 10).

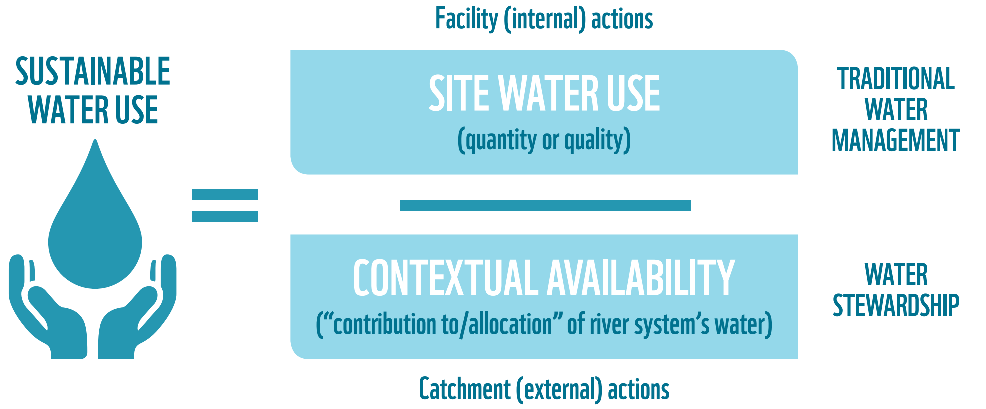


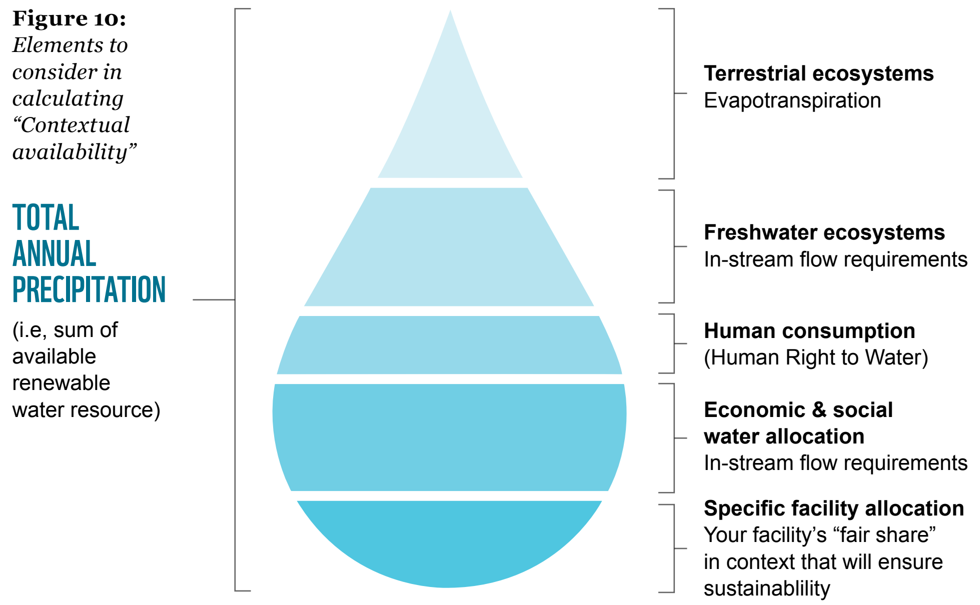
Figure 9: *How a Context-based Water Target is formulated based on a site's proportionate responsibility to contribute to a sustainable river system*

The process of setting CBWTs can help evaluate whether investments are better placed internally or externally to most efficiently contribute to river basin challenges. For example, through the CBWT process, a company can understand its appropriate contribution to the environmental flow needs of a river, with flow targets ideally accounting for river benefits such as fisheries or sediment transport. The development of CBWTs can be an important catalyst for discussions of formal water allocation, both voluntary and regulatory, and potential needs for policy reform.

Context-based Water Targets, now being discussed alongside the Global Commons initiative, offer a tangible pathway for companies to implement practices that help to protect, maintain and enhance the value of rivers. CBWTs can also be potentially linked to additional incentives (e.g., pay-for-performance green bonds with performance linked to attaining CBWTs, certification under the Alliance for Water Stewardship or conditional finance) to catalyze broad uptake.

In summary, CBWTs offer a pathway not only to contribute to improving the status of river basins, but also to open up policy dialogue around how we value and govern our rivers. WWF is now piloting these approaches, working with companies, partner organizations, and academics to offer technical guidance on methods and governance.

Figure 10: *Elements to consider in calculating "Contextual availability"*



© WWF International NB Adapted from McElroy & van Engelen (2012)

10. THE ALLIANCE FOR WATER STEWARDSHIP

The Alliance for Water Stewardship (AWS) is a global membership-based collaboration whose mission is to lead a global network that promotes responsible use of freshwater that is socially and economically beneficial and environmentally sustainable.

AWS employs a global water stewardship system, centered on the International Water Stewardship Standard (the AWS Standard), that provides a globally-applicable framework for major water users to understand their water use and impacts, and to work collaboratively for water stewardship - and stronger water governance – within a catchment context. The AWS Standard is in turn supported with training, membership and a certification programme that drives, recognizes and rewards good water stewardship performance in water governance, water balance, water quality and important water-related areas. Established in 2009, AWS now has over 100 members, hundreds of sites moving towards certification, and thousands of sites implementing the standard.

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Bankable Water Solutions

To achieve the SDGs, the world will need an additional US$2.5 trillion of investment annually[97]; the Organization for Economic Co-operation and Development (OECD) estimates that at least US$1 trillion of annual investment is needed for wastewater treatment, water plants, and supply networks alone. The gap can only be filled by leveraging philanthropic and public sector capital with capital from the private sector. While this blended finance approach is receiving increasing attention, a number of constraints are limiting its application, including a lack of local sponsors with the capital to develop the business case and weak regulatory environments that deter investors.

Furthermore, traditional investment approaches risk repeating past outcomes, in which a narrow set of objectives (Box 3) are pursued to the detriment of rivers' other diverse values. Investors and banks have strong interest in investing in more sustainable water projects, but currently there is a limited pipeline of viable projects.

WWF is developing a 'Bankable Water Solutions' initiative that is intended to address these investment and sustainability challenges (Figure 11). Through this initiative, WWF hopes to redirect investment from poorly planned infrastructure projects toward projects that will have positive impacts on river basins, while providing investors with an acceptable return on their investment.

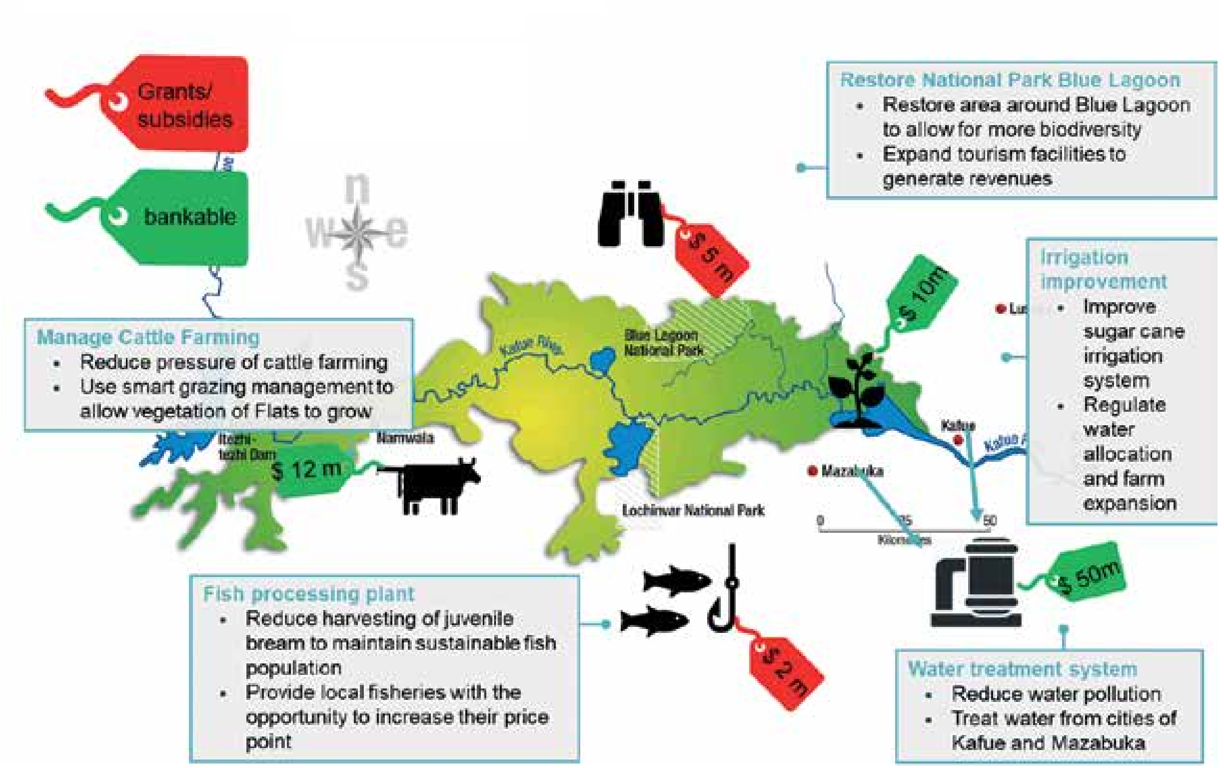
Bankable water solutions can involve projects in several categories:

- System-scale planning for sustainable infrastructure, including investment mechanisms that promote early planning for sustainable projects and low-risk investments (see Box 7).
- Renewable energy: the cost of wind and solar projects has fallen dramatically in the past few years and increasing reliance on these generation sources can reduce the demand for hydropower projects, which have high negative impacts on environmental and social resources. In some places, wind and solar can benefit from the suite of services and partnerships mobilized through bankable solutions.
- Clean technology for water management and treatment, including improvements to irrigation systems and pollution management.
- Investing in ecosystems for improving water quality or reducing flood risk (see Box 11).

KEY CHARACTERISTICS OF WWF'S BANKABLE WATER SOLUTIONS INITIATIVE INCLUDE:

1. **Scale:** While investments flow toward individual projects, these projects should be planned at a basin scale to better manage cumulative impacts and/or to achieve system-scale conservation benefits.
2. **Integration across financial players:** Financial Institutions (FIs) often operate in silos. WWF has relationships with various FIs, including public and private institutions, banks and investors. This means that we can broker relationships and introduce opportunities that siloed FIs do not see. We can move them beyond the simple transaction of a project to the broader opportunities that exist by matchmaking partners.
3. **Supply chains:** Through relationships with suppliers (assets) and supply chains, we can involve global brands – the companies that source from these areas – and involve them in investment-based solutions.
4. **Leveraging bankable solutions with other sources of funding:** While bankable water solutions focus on investments that can produce a return, the initiative's objectives overlap with those of traditional conservation. By taking a basin-scale approach, we can mobilize conservation funding that will have synergistic impacts alongside bankable investments as well as 'fund the un-fundable' by supporting the institutions, regulations and governance that are critical to the objectives of bankable solutions but are not on the agenda of FI project financiers.
5. **WWF will help raise the seed capital** to bring bankable projects from a concept or idea to a pre-feasibility phase, where we have made the business case, specified the revenue model and identified a potential project sponsor. Once the sponsor and investor have been identified to fund the subsequent phases, WWF's role will change to an advisory and monitoring role.

LANDSCAPE FINANCE PLAN FOR KAFUE FLATS, ZAMBIA – INCLUDING BANKABLE WATER SOLUTIONS



The bankable water solutions initiative creates an investment structure through which blended finance can flow to support projects that produce a return while maintaining or restoring rivers' diverse values, including those that are hidden and overlooked – and often negatively impacted – by status quo approaches to investment. A system-scale approach can align individual investments with landscape-scale conservation objectives and identify needs or opportunities that will require traditional conservation funding. Through this approach, bankable solutions can help resolve tradeoffs between infrastructure development and conservation. The overarching goal of this initiative is to help shift investment decisions so that they recognize and support river values up front, before these values are lost to poorly planned infrastructure or water pollution.

Figure 11: *A set of potential bankable water solutions for the Kafue Flats region, part of the Zambezi River basin in Zambia. The system-scale approach identifies a suite of projects that would work together to collectively contribute to landscape conservation objectives, as well as identify how to combine bankable solutions (that have an investment return, noted in green) with traditional conservation funding (grants and subsidies, noted in red) for synergistic impact.*

11. INVESTING IN ECOSYSTEMS

Improving the condition of rivers, wetlands, and other freshwater ecosystems can improve water quality and the resiliency of systems – both ecosystems and infrastructure systems – to disturbances such as floods and droughts.

Last year, the utility Anglian Water in Great Britain raised £250 million in a green bond jointly arranged by the bank ING. Bond proceeds will be invested in a broad range of ecosystem-related interventions intended to increase drought resilience.

In California, privately funded forest restoration programmes – thinning forests that have become unnaturally dense due to a century of suppressing the natural fire regime – are improving forest health and reducing the risk of wildfires. By reducing rates of evapotranspiration from overly dense forest, this intervention also allows forests to release more water into downstream reservoirs, benefiting hydropower and water supply. The work is funded by a 'Forest Resilience Bond', which pays out to investors when projects meet pre-agreed goals.

Additional opportunities may come from reducing flood risk through investments in urban green infrastructure, with recent floods in Houston and Bangkok illustrating the urgent need for strategies that can reduce flood risk for major cities.

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4

CONCLUSIONS

Rivers are central to most nations' histories and cultures, weaving their way through songs, stories and myths. They have been tapped for a range of benefits, including hydropower and irrigation, delivered through often extraordinary infrastructure projects that have spurred economic growth.

However, these projects were built to provide a narrow set of benefits and without consideration for the much broader range of benefits that rivers can support. These broader benefits often remain hidden to decision makers – hidden, that is, until crises arise. Due to their low profile, these diverse values of rivers have declined or been lost across the world, often because they were not fully understood or recognized in the first place or because their loss was viewed as unavoidable collateral damage for economic growth – such as the dramatic decline of the Columbia River's massive runs of salmon.

Without a change in how we value and manage rivers, this narrow approach, and consequent losses, will play out in similar ways in river basins around the world, with significant negative consequences for economies. This report emphasizes that these losses are not inevitable and unavoidable. Existing solutions, alongside emerging innovations, point toward much greater potential to reconcile economic growth with healthy rivers.

Fulfilling this potential will require a new way of valuing rivers' diverse benefits, supported by policies and practices designed to maintain or restore them. Methods to quantify these benefits have made considerable progress in the past two decades, such as ecosystem service valuations. However, to date, the results of improved valuation have had limited impact on policies and practice.

Thus, valuing rivers – effectively managing them for their full range of benefits – requires far more than just rigorous valuation of those benefits. Although a foundation of strong science is necessary, it is not sufficient. Equally as important are factors such as who collaborates on those valuations, whose views are represented, and how those values are communicated to important audiences that can form coalitions to support improved management.

This report provides a framework for improving how societies measure, value, and promote rivers' diverse benefits, adapted from a recent framework on valuing water To move beyond valuation, the framework encompasses approaches to communicate this value to diverse audiences and build coalitions to support improved management; and a set of promising governance structures needed to make these reforms and innovations widespread and durable, with roles for government, financial institutions and the private sector.

The approaches described under this framework are relatively new and, while progress is being made, much work remains to be done: the full value of rivers is still relatively unknown to decision makers, or to people in general – most sectors and people who depend on healthy rivers do not fully recognize this flow of benefits.

We hope the framework offered in this report will help governments, companies and communities to better understand rivers' diverse values and then collaboratively work on the solutions needed protect and restore them.

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THE FRAMEWORK'S MAJOR COMPONENTS INCLUDE:

- **Measure:** Sustainable river management will require a foundation of greatly improved measurement of benefits, based on rigorous understanding of key river processes and relationships. The so-called "Fourth Industrial Revolution" offers a number of promising pathways to improve how we measure water and river systems.
- **Value:** Various methods have been developed, or are emerging, to improve the valuation of water and rivers' services, including rapid progress in quantifying ecosystem services. However, improved valuation methods and results will not have major impacts on policy and management unless this information is delivered to the necessary audiences – including powerful decision makers not directly involved in river management – in a format that they find compelling.
- **Understand tradeoffs:** Even with improved measurement and valuation of resources, decision making about river management will require navigating difficult tradeoffs. Decision science has recently produced new approaches to integrate a more diverse set of values into planning, management and policy decisions.
- **Improve governance:** Implementing decisions and ensuring that progress is durable requires effective water-management institutions and governance, with roles for government, financial institutions and the private sector.

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Valuing rivers

500 MILLION

People live on deltas sustained by sediment from rivers

12 MILLION

Tonnes of freshwater fish caught per year

19%

Of global GDP comes from watersheds with high to very high water risk

2 BILLION

People depend directly on rivers for drinking water

Working to sustain the natural world for people and wildlife

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