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NATURE-BASED SOLUTIONS FOR DISASTER RISK MANAGEMENT

GFDRR Global Facility for Disaster Reduction and Recovery

WORLD BANK GROUP

PROFOR INNOVATION AND ACTION FOR FORESTS

WORLD RESOURCES INSTITUTE

Nature-based Solutions (NBS) that strategically conserve or restore nature to support conventionally built infrastructure systems (also referred to as gray infrastructure) can reduce disaster risk and produce more resilient and lower-cost services in developing countries. In the disaster risk management (DRM) and water security sectors, NBS can be applied as green infrastructure strategies that work in harmony with gray infrastructure systems. NBS can also support community well-being, generate benefits for the environment, and make progress on the Sustainable Development Goals (SDGs) in ways that gray infrastructure systems alone cannot.

Though NBS approaches have yet to be fully integrated into decision-making or to compel widespread investment in developing countries, this is on the brink of change. Developing countries and their partners (including multilateral development banks and bilateral agencies) are increasingly utilizing NBS in DRM, as well as in water security, urban sustainability, and other development projects. The growing number of NBS projects offer lessons and insights to help mainstream NBS into development decision-making. As more disaster risk managers understand and integrate well-designed NBS into DRM projects, more finance can be routed to nature-based projects that are cost-effective and resilient. With that goal in mind, the World Bank's Nature-based Solutions Program aims to facilitate uptake of NBS in water management and DRM projects.

Contents

This booklet is for staff at governments, development finance institutions (DFIs), and other development institutions to understand how NBS can enhance DRM, and how to begin integrating these approaches into projects. The booklet illustrates NBS through 14 real-world examples. Its main findings draw on the forthcoming report *Integrating Green and Gray: Creating Next Generation Infrastructure,* published by the World Bank and World Resources Institute. The booklet's three sections cover the following:

- The World Bank's Nature-based Solutions Program and World Bank projects already investing in NBS components
- Examples of NBS for three types of hazards: coastal flooding and erosion, urban stormwater flooding, and river flooding
- Guidance to support implementation of NBS in DRM, including a high-level review of emerging policies and financing approaches that encourage the use of NBS

About the World Bank Nature-based Solutions Program

Established in 2017, the World Bank NBS Program informs and enables the World Bank operational teams and clients to make use of natural and modified ecosystems for functional purposes, to reduce risks associated with natural hazards and achieve other development objectives.

WEBSITE: *www.naturebasedsolutions.org*

PROGRAM OBJECTIVES

The program seeks to inform and enable World Bank operational teams and clients to incorporate NBS considerations into project plans and investments by

- identifying NBS investments across the World Bank portfolio;
- addressing challenges and obstacles within the institution and in the client engagement process;
- mainstreaming NBS among clients, management, and operational staff by providing technical guidance and conducting pilot projects; and
- fostering knowledge exchange among staff, and with practitioners outside the World Bank.

RELATED PUBLICATIONS

The World Bank NBS Program has been exchanging knowledge, experiences, and lessons learned among stakeholders to enhance the planning and implementation of NBS across the World Bank portfolio. Key resources include the following:

- **Integrating Green and Gray: Creating Next Generation Infrastructure** (Browder et al. Forthcoming)[1]
- **Implementing Nature-based Flood Protection: Principles and Implementation Guidance** (Available in English, Spanish, and French) (World Bank 2017)[2]

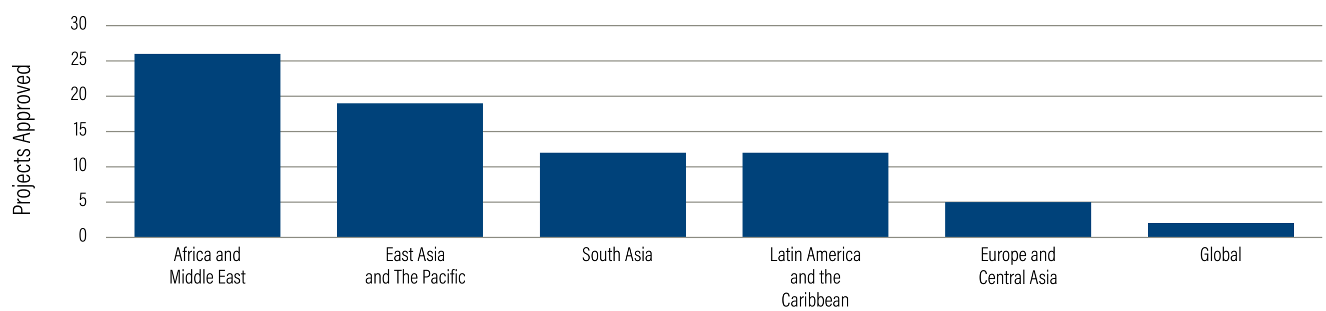
- **Managing Coasts with Natural Solutions: Guidelines for Measuring and Valuing the Coastal Protection Services of Mangroves and Coral Reefs (**World Bank 2016)[3]
- **The Role of Green Infrastructure Solutions in Urban Flood Risk Management** (Soz et al. 2016)[4]

Nature-based Solutions in the Disaster Risk Management Portfolio

From 2012 to 2018, the World Bank's DRM portfolio totaled US$52.87 billion across 681 projects. Over this same period, the World Bank approved 76 DRM projects that utilize NBS in project subcomponents (Figure 1). The total value of subcomponents that utilize NBS is $2 billion (Figure 2). These projects target several hazards and risks (see Figure 3; note some projects apply to more than one hazard).

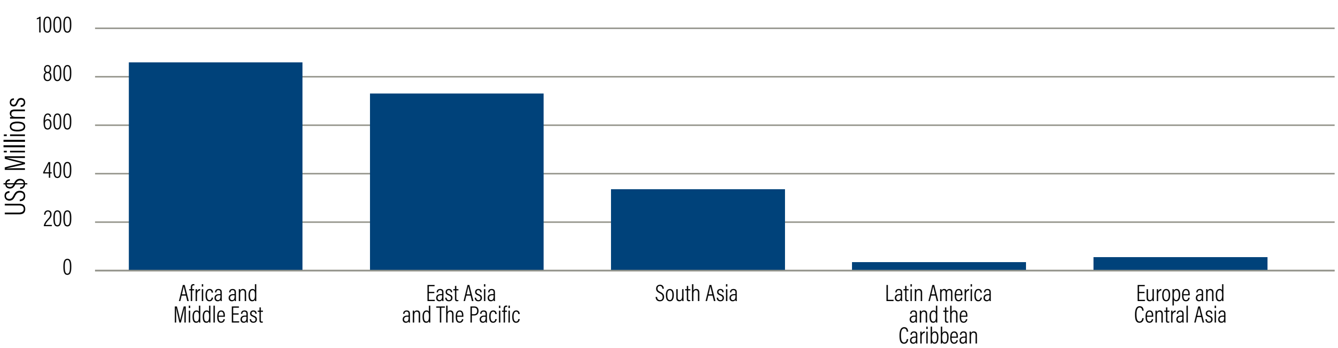
Six World Bank Global Practices have implemented these projects with NBS components: Environment and Natural Resources (35 projects); Social, Urban, Rural and Resilience (29); Agriculture (5); Water (5); Social Protection and Labor (1); and Transport and Information and Communication Technology (ICT) (1).

FIGURE 1 | **Nature-based Solutions in the Disaster Risk Management Portfolio**



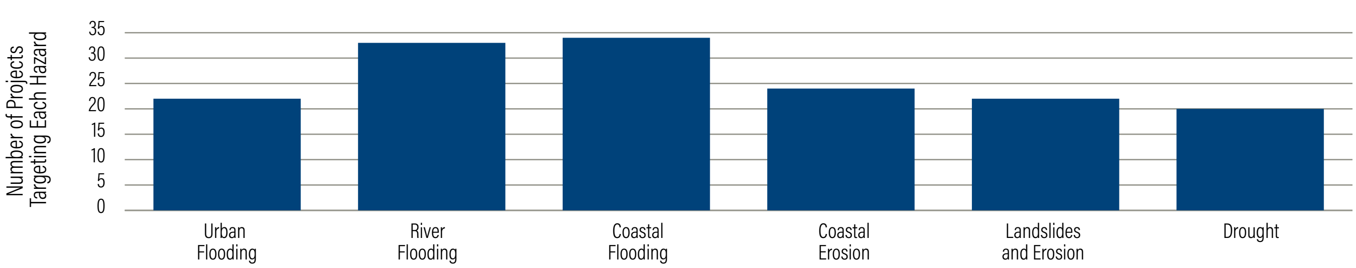
Source: Adapted from WRI and World Bank (forthcoming)[1].

FIGURE 2 | **Investments in Project Components Containing Nature-based Solutions by Region**



Source: Adapted from Browder et al. (forthcoming)[1].

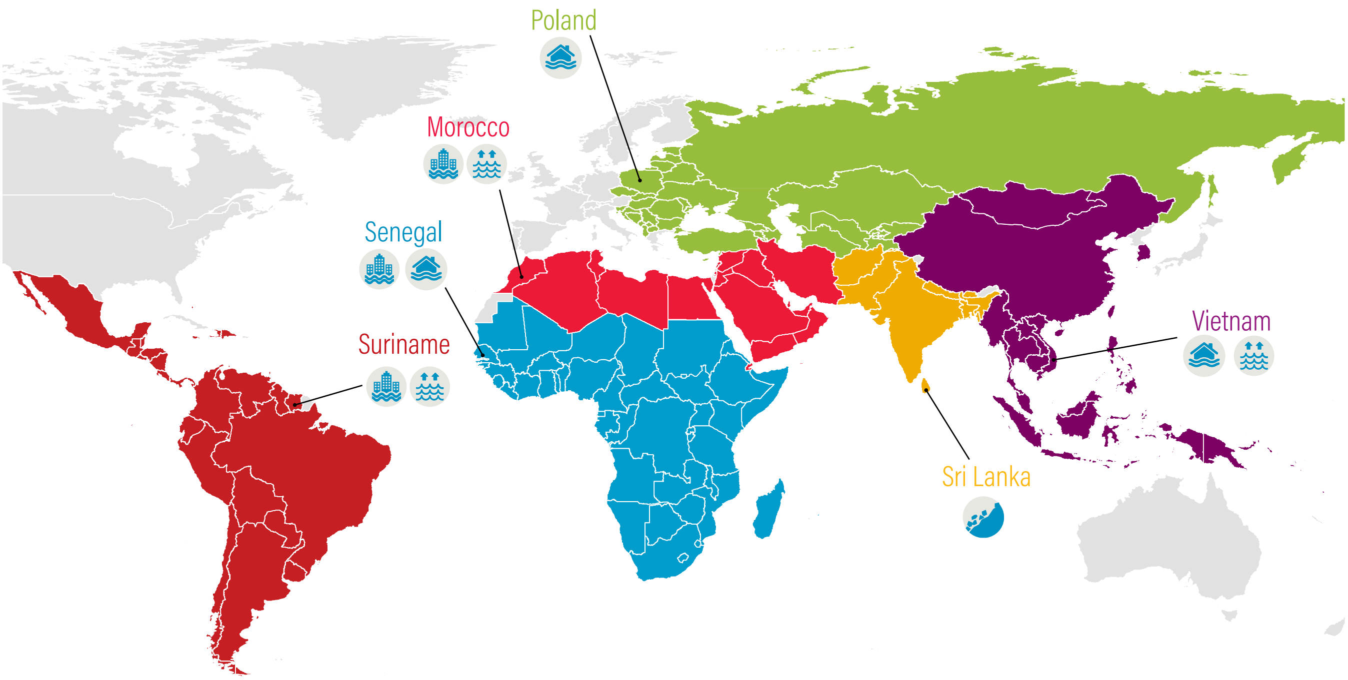
FIGURE 3 | **Hazards Targeted by Projects Containing Nature-based Solutions**



Source: Adapted from Browder et al. (forthcoming)[1].

FIGURE 4 | **Highlights of DRM Projects with NBS**

The map below highlights some examples of DRM projects and their NBS components.



Coastal & urban flooding | Coastal erosion | River flooding | Landslides

LATIN AMERICA & THE CARIBBEAN
Greater Paramaribo Flood Risk Management

Location: Suriname
Challenges: Coastal & urban flooding; coastal erosion
NBS: Mangrove restoration; rivers & floodplain management
Cost of NBS-related Component: US$ 225,000

EUROPE & CENTRAL ASIA
Odra-Vistula Flood Management Project

Location: Poland
Challenge: River flooding
NBS: Dry polder & embankment retrieval
Cost of NBS-related Component: US$ 22M

AFRICA
Stormwater Management and Climate Change Adaptation Project

Location: Senegal
Challenge: Urban & river flooding
NBS: Artificial & natural retention ponds; wetlands
Cost of NBS-related Component: US$ 4M

SOUTH ASIA
Forest-based Landslide Risk Management Program

Location: Sri Lanka
Challenge: Landslides
NBS: Restoration of forests & vegetation
Cost of NBS-related Component: US$ 150,000

MIDDLE EAST & NORTH AFRICA
Integrated Coastal Zone Management Project

Location: Morocco
Challenge: Coastal & urban flooding
NBS: Forests & vegetation; inland & coastal wetlands; dunes & beaches
Cost of NBS-related Component: US$ 4M

EAST ASIA & THE PACIFIC
Mekong Delta Integrated Climate Resilience and Sustainable Livelihoods Project

Location: Vietnam
Challenge: Coastal flooding & erosion; river flooding
NBS: Mangrove restoration & re-connect river
Cost of NBS-related Component: US$ 243M

MITIGATING DISASTER RISKS WITH NATURE-BASED SOLUTIONS

This section describes a variety of NBS that can help mitigate the impact of coastal flooding and erosion, urban flooding, and river flooding. It highlights risk-reduction potential, estimated costs of implementation (where available), and examples of where and how NBS have been used—drawing on experiences from the World Bank project portfolio as well as other sources.

The magnitude of costs and benefits for nature-based solutions, and their suitability for local contexts, vary widely according to geography, and for several NBS very few estimates are available. This booklet provides estimates from existing literature to give a sense of potential values, but these estimates are not directly applicable to every site.

NATURE-BASED SOLUTIONS FOR COASTAL FLOODING AND EROSION

Average global flood losses in major coastal cities are expected to spike from $6 billion per year in 2005 to $52 billion per year by 2050[5]. Coastal flooding is on the rise in part due to ecosystem degradation (e.g., overextraction of natural resources, loss of wetlands and mangroves, and pollution that harms species), as well as human settlement in low-lying coastal areas. Climate change and sea-level rise are exacerbating these trends.

NBS can help stabilize shorelines and attenuate waves to reduce flooding and erosion impacts. Integrating these solutions into coastal development and flood risk mitigation strategies could enhance overall flood control system performance.

- **Coastal wetlands, such as mangroves and salt marshes,** can stabilize coastlines by trapping sediment with their root systems, and by reducing wave height and velocity with their dense vegetation. Salt marshes can reduce nonstorm wave heights by an average of 72 percent, and mangroves, by 31 percent[6]. Median restoration costs for salt marshes are $1.11/square meter (m^2) (ranging from $0.01 to $33.00), and $0.1/ m^2 for mangroves (ranging from $0.05 to $6.50). It can be two to five times cheaper to restore coastal wetlands than to construct submerged breakwaters to deal with wave heights of up to half a meter.
- **Coral and oyster reef systems** can control coastal erosion by reducing wave velocity. By one estimate, coral reefs reduce nonstorm wave heights by 70 percent[6]. Median restoration costs for coral reefs are $166/m^2 (ranging from $2 to $7,500), while oyster reef restoration costs range from $107 to $316/m^2.
- **Sandy beaches and dunes** prevent coastal erosion caused by strong winds, waves, and tides. They can also stop waves and storm surge from reaching inland areas. The natural services these NBS provide can be enhanced through artificial sand nourishment, which costs between $6,500 to $16,400/meter (m)[7]. Revegetating and restoring sand dunes can cost between $100 to $16,400/m.
- **Seagrass** helps stabilize sediment and regulates water currents that contribute to coastal erosion. Seagrass beds reduce non-storm wave height 36 percent on average[6]. A cost of $11/m^2 (ranging from $0.20 to $410) is estimated for seagrass restoration[8].

Additional benefits of NBS: In addition to protecting coastlines from flooding and erosion, these NBS can generate income for local communities by underpinning fisheries, tourism, and recreation; some nature-based solutions can aid in the storage of freshwater supplies and improve water quality; they also enhance habitat and biodiversity. Intentional design of NBS to work in combination with gray infrastructure can achieve coastal resilience as well as these additional benefits.

Photo by Blue Forests/Flickr

Examples of NBS in Action

UNITED STATES | Oyster Reef Restoration[9]

Oyster reefs in the Gulf of Mexico have been degraded from decades of unsustainable harvesting, pollution, and diseases. The Nature Conservancy has undertaken several reef restoration projects to rejuvenate oyster reefs and create a healthy marine ecosystem in the Gulf that naturally protects the coastline while providing habitat, food, and cleaner waters. In Mobile Bay, Alabama, $3.5 million has been spent on efforts to successfully restore 5.9 kilometers (km) of oyster reefs that have reduced wave height and energy of average waves at the shoreline by 53 to 91 percent[9]. The reefs have also produced 6,560 kilograms (kg) of seafood per year—a weight equivalent to half the total oysters harvested in Alabama in 2015. These efforts also help filter nitrogen pollution that contributes to conditions that can be fatal for marine life.

THE NETHERLANDS | Sand Nourishment[10]

To help protect the Delfland Coast from erosion and inland flooding, the Dutch Government must periodically replenish sand along its dunes and beaches. The traditional method for doing so, however, is costly—it requires small, frequent nourishment operations on an as-needed basis. In 2011, the government took a different approach called the "Sand Motor." With an investment of nearly $100 million, it deposited a large volume of sand (21.5 million cubic meters [m^3]) all at once to let the sand naturally distribute itself across the coastline and replenish the natural sand dunes. Initial findings indicate the shoreline has indeed grown beyond the original deposit, although the dunes have grown more slowly than expected[10].

VIETNAM | Restoring Mangrove Forests[11]

In the late 1980s, rapid aquaculture expansion along the northern coast of Vietnam caused significant loss of mangrove forests, which in turn decreased natural defenses against coastal floods and erosion in an area with a rapidly growing population. Recognizing that the restoration of mangrove forests could help mitigate the impact of disasters and protect livelihoods, in 1994, the Vietnam Red Cross launched the Mangrove Plantation and Disaster Risk Reduction Project to enhance existing gray infrastructure and reduce the risk of flooding. By 2010, $9 million was invested to restore 9,000 hectares (ha) of mangroves along the shores of 166 communes as well as 100 km of dike lines. Cost of damages to the dikes was reduced by $80,000 to $295,000, and $15 million was saved in avoided damages to private property and other public infrastructure[11].

VEGETATED DUNES AND SANDY BEACHES HELP ATTENUATE WAVES AND STABILIZE THE SHORELINE

Source: |vv@ldzen|/Flickr

NATURE-BASED SOLUTIONS FOR URBAN FLOODING

Of the total global population, 68 percent will live in cities by 2050, up from 55 percent in 2018[12]. Heavy rainfall in low-drainage urban areas poses flood hazards and overwhelms water infrastructure systems, resulting in system overflows that expose city residents to health risks. As urban populations grow and climate change shifts rainfall patterns, people are at increasing risk of urban flooding. Rapid urbanization often entails informal settlements in areas with high flood risk, such as floodplains and riverbanks, exposing the urban poor to higher risk of floods.

NBS for urban flooding can help increase onsite stormwater absorption. They can be applied from the house or building level to landscape scale, are often used in combination with multiple NBS and gray infrastructure components, and are most effective when integrated into comprehensive urban development plans.

- **Green roofs** reduce stormwater runoff by promoting rainfall infiltration on the tops of buildings. Green roofs retain 50 to 100 percent of the stormwater they receive[13]. At $110 to $270/m^2, green roofs are more than two to five times more expensive to install than traditional roofs. However, they are of comparable cost over their life cycle, given that green roofs typically last twice as long as traditional roofs, and they also insulate buildings, which cuts heating and cooling bills[14].
- **Permeable pavements** are pervious concrete, asphalt, or interlocking pavements that allow rainwater to infiltrate where it falls, thereby reducing stormwater runoff. At $5 to $100/m^2, installation costs are roughly two to three times higher than for regular asphalt or concrete[15]. However, some applications have demonstrated a 90 percent reduction in runoff volumes[16].
- **Bioretention areas, including rain gardens and bioswales,** are vegetated trenches designed to receive runoff in a specific location to help control stormwater. A cost of cost between $110 to $430/m^2 is estimated for industrial bioswales[17]. In addition to controlling peak flows, bioretention areas can filter pollutants and have been shown to remove up to 90 percent of heavy metals from stormwater[16].
- **Open spaces such as parks and greenways** can be intentionally constructed or protected in strategic locations to capture runoff from upstream basins and adjacent areas. The cost of open spaces is highly variable and largely dependent on land prices. The benefits can be substantial: a study of green spaces in Beijing, China, showed that these areas stored 154 million m^3 of rainwater, which corresponds roughly to the annual water needs of the city's urban ecological landscape[18].
- **Constructed wetlands** can capture and retain stormwater, allowing for greater water infiltration. The cost of constructed wetlands may range from $7 to $15/m^2 and are usually less expensive than built (gray) options for the same function, though these costs are also highly variable according to land costs[19]. An acre of wetland can store 3.8 to 5.7 million liters of floodwater, reducing the peak load on built stormwater and wastewater systems.

Additional benefits of NBS: Beyond helping control urban flooding and preventing stormwater pollution, these NBS create additional benefits for urban communities. For example, urban green spaces have been shown to increase property values by 5 to 15 percent, while wetlands create birdwatching and recreation opportunities[20]. Many of these NBS mitigate the heat island effect and provide a cool refuge for city dwellers and wildlife.

Examples of NBS in Action

SRI LANKA | Urban Wetlands[21]

Metropolitan Colombo is surrounded by large, interconnected natural and managed wetlands that help retain floodwaters. However, rapid urbanization in recent decades has caused steady wetland degradation, and a 30 percent reduction in wetlands' water-holding capacity. In 2010, the city experienced a series of record-breaking flooding events that brought unprecedented economic losses. To reduce flood risks, the Government of Sri Lanka implemented the Metro Colombo Urban Development Project, which combines green and gray infrastructure—wetland conservation, flood retention parks, and traditional concrete bank protection walls. The integration of wetlands and flooding parks allows rainwater to infiltrate slowly, decreasing the volume of water that must be moved through the overtaxed built system. Economic analysis has found, the more wetlands are conserved, the greater the payoff in flood protection and other benefits, like wastewater treatment[21].

UNITED STATES | Mixing Multiple NBS for Urban Stormwater Management[22, 23, 24]

One-third of Portland, Oregon, has a combined sewer system that transports its stormwater runoff and sewage to treatment using a single pipe. Over time, Portland grew, and the system struggled to handle the growing volumes of sewage and stormwater runoff from impervious surfaces, resulting in increased frequency of combined sewer overflows (CSOs) that directly affected water quality and community health. From 1990 to 2011, the City implemented a CSO control program that expanded gray infrastructure, like tunnels and treatment facilities, to reduce its CSOs and clean up local waterways[22]. As a complement to this program, the City also implemented a range of programs, policies, and incentives to spur the use of urban NBS to help keep stormwater out of combined sewers and control overflows, such as its Green Streets program. Since 2007, the program has installed permeable pavements and bioswales throughout the city and achieved an 80 to 94 percent reduction in peak flow in the targeted areas[23]. Portland officials estimate $9 million in their total NBS investment portfolio has yielded a savings of $224 million in CSO costs related to repairs and maintenance[24].

CHINA | Promoting Public-Private Partnerships to Scale Up Urban NBS[25]

China's rapidly growing urban population has increasingly encountered serious water challenges associated with insufficient water infrastructure, sprawling development, degradation of waterways, and intensifying storms: in fact, 62 percent of cities experience flooding, and half are considered water-scarce. To address these growing hazards, the Chinese Government is supporting the development of "sponge cities" by providing funding and technical support to cities to implement NBS to capture, store, filter, and purify rainwater for reuse. Between 2015 and 2016, the government supported 30 cities, which have constructed green roofs, permeable pavements, and wetland restoration[25]. The central government is directly providing between $59 and $88 million per year to each of its 30 pilot cities for three consecutive years as start-up capital to help them devise and construct NBS. This investment is intended to inspire the creation of public-private partnerships (PPP) that will unlock private finance to meet overall investment needs[25]. China's Ministry of Finance created a strategy to support the PPP model by soliciting private investment in construction projects and formalizing the government procurement process for PPPs[25].

RESTORED URBAN WETLANDS AT THE BEDDAGANA WETLAND PARK, SRI LANKA

Source: World Bank

NATURE-BASED SOLUTIONS FOR RIVER FLOODING

River flooding is a common natural process that is essential for productive river-floodplain ecosystems. It also poses serious hazards as population growth and economic development in flood-prone areas continue to rise. Climate change and aging flood-management infrastructure only compound the risk. Economic losses from river floods have increased by 6 percent per year on average since the 1960s[26].

Integrating NBS into flood control systems can complement engineered infrastructure and relieve pressure on the system, and is especially effective at mitigating impacts of short-duration floods. NBS for river flood risk mitigation often involve large-scale interventions, and therefore must be carefully planned to meet the needs of affected communities.

- **Floodplains and bypasses** can store and slowly convey water and sediment that overtops riverbanks during flood events. Bypasses comprise built diversions, like weirs, to control floodwater volume, while floodplains are naturally occurring areas that absorb water. The cost of restoring and reconnecting floodplains varies with land prices, roughly $10,000 to $800,000/ha in Europe[27].
- **Inland wetlands** can reduce flood risk by storing water during wet periods and releasing it during dry periods. Their storage capacity depends on the type of wetland and its location, but some can store up to 9,400 to 14,000/m^3 of floodwater per hectare[28]. Estimated costs of wetland restoration are $33,000/ha [29].
- **Stream beds and banks** can help slow the river flow when natural functions are preserved or restored, such as a river's meandering path or vegetated riparian areas. This can sometimes require removing concrete reinforcements and revegetating riverbanks or riparian areas. Restoration costs can vary widely: channel rehabilitation costs range from $16,000 to $53,000/km of river[30]. The benefits can be substantial: for example, setting back levees along the Middle Mississippi River in the United States would decrease expected annual damages by 55 percent in urban areas[31].
- **Upland forests** with deep soils can help slow and retain runoff, resulting in lower peak flow. Forest management is most effective at retaining and slowing moderate floods of short duration before soils become saturated[32].The cost of forest restoration (excluding land acquisition costs) varies but is on average between $2,000 and $3,500/ha[29]. A review of restoration studies found that 82 percent reported a decrease in peak flow after restoring upland areas[33].

Additional benefits of NBS: Along with reducing flooding risks, NBS implemented along rivers can have a range of additional benefits for both people and the natural environment. Restoring riverbanks and flood plains can improve downstream water quality and provide important fish and migratory bird habitats[34]. Slowing down flood waters in river basins can also increase the deposits of nutrient-rich sediments that help to create fertile soils for agriculture[35].

Photo by U.S. Army Corps of Engineers/Flickr

Examples of NBS in Action

POLAND | Remeandering Rivers[36]

In response to a series of catastrophic river flooding events in 1997, 2006, and 2010, the Polish Government and the World Bank implemented two hybrid NBS projects in the Odra and Vistula River basins. These projects take a systems approach that make investments to deliver flood protection services to the entire population by protecting the country's robust economic centers, as opposed to standalone interventions that only benefit the local community. A range of project components are being implemented that combine existing gray infrastructure with natural features in the river basin. For example, expanding the river floodplain by retrieving embankments and improving existing levee systems and drainage canals helps enhance flood retention capacity and lower peak flooding levels in upstream areas. These efforts not only protect the immediate rural communities, but also the large economic and urban centers downstream[36].

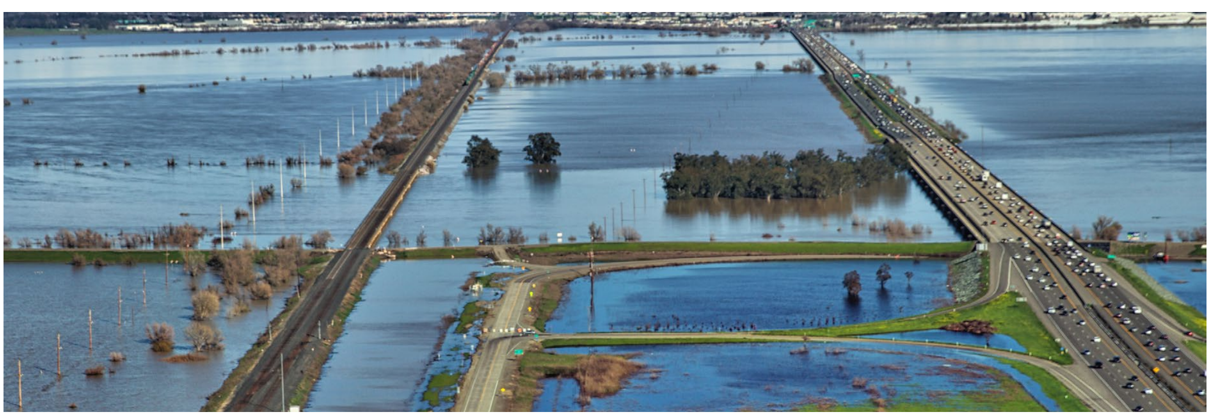
UNITED STATES | Bypassing Floodwaters[37, 38]

Major flooding events in the late 1800s in California's Sacramento Valley brought realization to communities and policymakers that existing single-channel, gray infrastructure approaches to flood management were insufficient to handle the volume of floodwaters in the region. At the turn of the century, opinions shifted in support of the implementation of a comprehensive, multichannel flood-control system. The resulting system is known today as the Sacramento River Flood Control Project and consists of a network of built levees and weirs, and natural bypasses that work together to route and control floodwaters from the main river channel to protect settlements along the river valley. The Yolo Bypass, for example, is an integral part of the hybrid NBS network, and receives overflow from the Sacramento River through weirs. The bypass consists of 240 km^2 of wetland area (65 km long); during large storm events, it conveys as much as 80 percent of floodwaters[37]. It also provides groundwater recharge, fosters wildlife habitat, and serves as agricultural land when not flooded[38].

CHINA | River Reconnection[39]

Widespread dam and dike construction in the Yangtze River Basin from the 1950s to 1970s fragmented the existing river-lake wetlands system. The fragmentation contributed to major flooding events that occurred in the 1990s, which resulted in thousands of deaths and billions in direct economic losses. To mitigate future flooding risks, the Chinese Government in partnership with the World Wildlife Fund (WWF) reconnected the Yangtze River with the disconnected lakes and rehabilitated the natural functions of the wetland system[39]. The reconnection project restored 448 km^2 of wetlands, which have a floodwater retention capacity of 285 million m^3. In one of the lake districts, the restoration of seasonal flooding increased fisheries production more than 17 percent[39]. Reconnecting the river-lake wetland system has helped reduce vulnerability to flooding and to increase wildlife populations.

VIEW OF THE YOLO BYPASS IN CALIFORNIA'S SACRAMENTO VALLEY DURING A FLOOD EVENT



Source: Pacific Southwest Region USFWS/Flickr

ENABLING AND IMPLEMENTING NATURE-BASED SOLUTIONS TO MANAGE DISASTER RISK

The previous section covered the variety of NBS that can be utilized to address development challenges and disaster risk, and highlighted their many advantages—they can be cost-effective, multifunctional, resilient, and they can empower communities. Yet, to date, the mixed success of NBS projects has revealed that these advantages may not be realized unless NBS is well-designed and efficiently implemented. Mainstreaming natural infrastructure into development decisions requires an expansion of high-quality demonstration projects as well as documentation of their results.

IMPLEMENTING NATURE-BASED SOLUTIONS

Lessons from existing NBS projects and guidance documents help demonstrate best practices for assessing, designing, and managing NBS projects. The World Bank (2017) guide *Implementing Nature-based Flood Risk Mitigation* sets out eight steps for the successful implementation of NBS for river flooding, with relevance to a broad set of NBS (see Figure 5, page 14). The World Resources Institute and World Bank's, forthcoming report, *Integrating Green and Gray: Creating Next Generation Infrastructure*, also offers high-level guidance to support design and implementation of successful NBS.

Integrating NBS considerations into development planning

Normal planning processes offer opportunities to define suitable roles for NBS to work in harmony with conventional DRM project components, such as gray infrastructure, for example:

- **Regional or sectoral planning processes:** land-use master plans, coastal zone plans, forest management plants, country- or state-level water resources plans, and river basin plans can be used to identify potential opportunities for NBS.
- **Infrastructure master planning:** Potential NBS investments can be considered in the menu of options to inform investment programs and financial needs.

If NBS opportunities can be confirmed at these early stages of planning, then resources can be directed to undertake detailed feasibility and design studies, explicitly considering linkages with gray infrastructure.

Assessment of projects with NBS (and green infrastructure) components

Conducting thorough assessments can help identify the right places to apply NBS, as well as inform the design of NBS. Key considerations for assessment, design, and implementation of NBS include the following:

Technical dimensions

- NBS can be functionally equivalent to gray infrastructure components. The performance of NBS in meeting a service provision target can be estimated through modeling.
- NBS can have variable service provision, large uncertainties, and possible failures, requiring thoughtful pairing and sequencing of infrastructure components to ensure resilience in a changing climate.
- NBS project viability depends on the willingness and capacity of impacted communities to operate the NBS or at least to work in harmony with it.
- Identifying key features of the target landscape—from ecosystem services and biodiversity to interdependencies with other ecosystems, people, and infrastructure—provides baseline information to help ensure interventions reconcile conservation and development needs without harming biological or cultural diversity, ecosystem services, or people and their livelihoods.

Social dimensions

- The main operators of NBS are often local communities, responsible for implementing land stewardship practices, and for maintaining the project over the long term. NBS employ strategies that impact land management, often across a landscape and across property boundaries or jurisdictions. For this reason, NBS sometimes impact more people than gray infrastructure projects do, and often impact multiple stakeholder groups.
- In certain situations NBS approaches may empower communities more than gray infrastructure does, by building communities' capacity to shift their natural resource practices toward more sustainable paradigms. To capture these opportunities, NBS should be assessed with systemwide analysis of the local socioeconomic, environmental, and institutional conditions.

Economic dimensions

- NBS can be low-cost, and cost-effective, helping enhance the cost-benefit ratio of development projects with NBS components.

- Economic analysis will undervalue the worth of NBS if the chosen analytical methods do not appraise NBS's delivery of important cobenefits, which can be both monetary and nonmarket.
- While NBS can in theory generate multiple benefits that help resolve social inequalities, they must be consciously designed to do so in practice. Evaluating who stands to gain from NBS, evaluating trade-offs, and incorporating adequate benefit-sharing schemes are therefore also critical components of NBS economic assessment.

The assessment and design needs of NBS may require different expertise, time, or resources than typical DRM projects. Making use of project preparation facilities can help ensure successful NBS assessment and design. Bilateral donor agencies can encourage development bank adoption of NBS by creating NBS project preparation and monitoring facilities.

FIGURE 5 | **Steps to Successful Implementation of NBS**

1 DEFINE PROBLEM, PROJECT SCOPE, AND OBJECTIVES

- Document stakeholder needs
- Map areas of interest depicting main risks and root causes to these risks
- Define measurable project objectives

2 DEVELOP FINANCING STRATEGY

- Create preliminary budget for project
- Review available and possible future resources

3 CONDUCT ECOSYSTEM, HAZARD, AND RISK ASSESSMENTS

- Map current and future hazard risk, exposure and vulnerability
- Review land use, ecosystem presence, and health
- Define importance of ecosystem for DRR

4 DEVELOP NATURE-BASED RISK MANAGEMENT STRATEGY

- Review feasible measures to reduce risk, their estimated effects and implementation steps
- Outline different strategies, their phasing in time with a focus on no-regret and less costly options first

5 ESTIMATE THE COST, BENEFITS AND EFFECTIVENESS

- Complete cost-benefit analysis including the full range of social and environmental benefits/impact

6 SELECT AND DESIGN THE INTERVENTION

- Design NBS, and create monitoring plan containing indicators, target, values, roles and responsibilities
- Define monitoring method and duration
- Establish maintainence plan

7 IMPLEMENT AND CONSTRUCT

- Determine lifetime of intervention, support regulatory frameworks to sustain and maintain intervention
- Construct NBS

8 MONITOR AND INFORM FUTURE ACTION

- Review monitoring reports
- Take needed action to change or improve the planet
- Share lessons learned

Source: World Bank 2017[2].

POLICY TO SUPPORT NATURE-BASED SOLUTIONS

One key to successful NBS implementation is understanding the institutional and policy environment that creates enabling conditions for NBS. In many cases, NBS can be used as one approach to achieve policy objectives on DRM and on other issues, including climate mitigation, water security, air quality, and public health. Development of robust and effective policy frameworks that create a role for NBS are essential for implementing high-quality NBS, as well as for catalyzing larger-scale NBS adoption.

A growing number of international agreements, like the Paris Agreement, High-Level Panel on Water, Sustainable Development Goals, and Sendai Framework for Disaster Risk Reduction, all include high-level commitments to promote ecosystem-based solutions such as NBS. These commitments are intended to filter down to actions at the country level, creating a window for policy changes. For example, among signatories of the Paris Agreement, 102 countries have now committed to restore or protect nature as an adaptation measure in their nationally determined contributions (NDCs)[40]. NBS were most commonly mentioned in NDCs of low- and lower-middle-income countries.

The following types of policies and government actions can help create an enabling environment to integrate NBS into DRM and other development strategies[1,41]:

- **Incorporating sustainable landscape vision into strategies and policies.** A high-level vision can help mediate traditional conflicts between economic growth and conservation interests, and identify strategic opportunities to deploy high-quality NBS. Land-use planning can help create a shared vision of the multiple goals of sustainable landscapes and help embed that vision into relevant jurisdictional strategies.
- **Creating incentives for local actors to participate in NBS.** This can include aligning public incentives with local or privately led NBS efforts to maximize the benefits of these efforts; as well as establishing national payment for ecosystem service programs or land acquisition programs for NBS.
- **Authorizing and enabling NBS and allowing for regulatory flexibility.** Governments can signal that NBS can be used to comply with environmental requirements of building codes, water safety regulations, and environmental impact mitigation plans. This includes using NBS to achieve climate mitigation and adaptation objectives, air quality and public health objectives, and the like. Similarly, governments can allow green infrastructure to be counted as a capital asset on the balance sheet for the services it provides.
- **Encouraging or requiring consideration of NBS by decision-makers.** Integrating NBS into planning often involves guidance or policy, such as providing criteria for infrastructure projects to include NBS evaluations in the planning, or adopting building codes or zoning laws that require a portion of space dedicated to green elements.
- **Supporting monitoring, research, and innovation on NBS** through government-sponsored research and data collection programs. Collecting baseline data on ecosystem health and following trends in environmental degradation, like deforestation and drought, as well as in restoration makes it easier to determine the suitability of NBS in meeting local needs and priorities, as well as to monitor NBS project impacts and promote mutual learning among projects.

- **Facilitating cross-sector coordination.** NBS often cross jurisdictions; their implementation can also benefit multiple sectors and agencies, and contribute toward a broad range of policy objectives. To operationalize NBS, governments should promote interagency coordination to ensure NBS do not incur red tape. Governments can grant legal authority to DRM agencies to implement cross-sector NBS to engage water, energy, and agriculture sectors, among others, in NBS projects. At the same time, governments can link NBS to existing policy objectives such as climate mitigation, adaptation, infrastructure, and water security.
- **Creating financing mechanisms to unlock investment in NBS.** Governments can earmark public funds for explicit use in NBS, or set policy that generates funds from other sources, such as land value capture, water tariffs, and insurance. Financing mechanisms for NBS is discussed further in the following section.

Importantly, many of the policies explicitly supporting NBS have only been in place for a short period of time, and some have yet to be implemented; thus, only very few policies have been rigorously tested and proven effective. Although there is no perfect formula for NBS policy, a growing number of states and countries have made progress that can serve as examples to others. Development agencies can help encourage policy reform along these lines by leveraging policy lending and engaging in dialogue with clients.

Examples of NBS in Action

PERU | Raising Revenue from Water Tariffs for Resilient NBS[42]

Peru has dealt with water crises related to El Niño for centuries, and climate change is only exacerbating these water woes. Recognizing this increased risk, in 2016, Peruvian lawmakers passed the Sanitation Sector Reform Law, which requires water utilities to earmark revenue from water tariffs for watershed conservation and climate change adaptation, and to consider these strategies in the official budgeting and planning processes. This policy change has already generated $30 million for NBS via payments for ecosystem services, and an additional $86 million for climate change mitigation and disaster risk management[42].

UNITED STATES | Recognizing NBS as Infrastructure at the State-Level[43, 44, 45]

Over the past 30 years more than 5 million hectares of land in the American West have burned due to wildfires, including important watersheds that are becoming degraded with the loss of trees and increased erosion[43]. In 2016, California passed a law that classified source watersheds as integral components of water infrastructure. This makes it easier for utilities to justify investments in watershed health as a means for combatting wildfires that can damage water infrastructure and threaten water supplies. The law allows for investment in NBS to support source watersheds using the same forms of financing typically reserved for gray infrastructure[44]. This policy change may motivate investments from utilities and other beneficiaries, as well as the state, in watershed health. One such project is the Forest Resilience Bond, which utilizes investor capital and cost-sharing among beneficiaries, like water utilities, to pay for benefits created by restoration activities and decrease the risk of severe wildfires[45].

COMMUNITY MEETING IN MKURANGA DISTRICT, TANZANIA

Source: Roots, Tubers and Bananas/Flickr

FINANCING FOR NATURE-BASED SOLUTIONS

Increased uptake of NBS depends on rerouting or unlocking new funds to support these projects. Presently, most NBS are funded through public and philanthropic means. These will continue to be important sources of funding, but these alone are not enough to meet the worldwide NBS investment opportunity. A variety of new financing approaches and mechanisms have emerged to blend public and private finance together to enable broader adoption of NBS.

In designing NBS projects, task team leads and project developers can take advantage of the following existing and emerging sources of funding for NBS. The choice of which funding mechanism to use should be guided by suitability for local context and the degree to which NBS will generate cash flows.

International public finance opportunities for NBS

International public finance and development aid are a primary source of available funding for NBS in developing countries. These include multilateral funds, multilateral development banks (including the International Bank for Reconstruction and Development [IBRD] and the International Development Association [IDA]), and bilateral sources like national development or aid organizations.

International public finance for NBS often takes the form of standard project financing where loan disbursements are made against payments to contracts as well as grants. The **Global Environmental Facility (GEF),** created in 1992, has supported NBS through investment in a wide range of projects that advance, for instance, integrated water resource management, the restoration of degraded lands, and special designation of protected areas[46]. The GEF Adaptation Fund was created in 2008 and has committed $517 million to projects in developing countries that are particularly vulnerable to climate change. This Fund has enabled NBS by promoting water management through ecosystem-based adaptation and through their support of natural systems increasing resilience in coastal areas[47].

Only a small sliver of these funding sources are dedicated to disaster risk reduction, and an even smaller amount of these funds are currently put toward NBS. That is now changing with the creation of new funds and utilization of financing mechanisms for NBS.

The **Green Climate Fund (GCF)** is one example. The GCF was created under the UN Framework Convention on Climate Change (UNFCCC) to provide grants, loans, equity, or guarantees to finance climate change mitigation and adaptation measures in developing countries. So far, $10.3 billion has been pledged, $3.5 billion committed, and $1.4 billion invested in 74 projects. The GCF has already funded a handful of projects with NBS components; it judges projects on their ability to avoid infrastructure and development lock-in, to reduce vulnerability and exposure to climate risks, and to generate multiple environmental benefits, among other criteria. The GCF aims to leverage private sector contributions and to support development of new markets[48].

Other applicable international development aid approaches include pay-for-success models (also known as pay-for-performance), where loan disbursements are made against actual results irrespective of any contractual arrangements. A **debt-for-nature swap** is another financing mechanism that can support NBS and is particularly helpful for developing countries with a large national debt and threatened natural ecosystems. The debt is canceled or restructured if a country agrees to invest in environmental protection measures.

Domestic public finance opportunities for NBS

Local and national governments often support NBS through **dedicated taxes, fees, and charges** that make up general revenue funds can be drawn upon to finance programs that invest in NBS, and can be specifically earmarked for investment in NBS-related projects. Much of these public funds are related to environmental objectives. For example, revenue **from compensatory mitigation and compensation fees** imposed on unavoidable impact to water is collected in 57 countries[49]. These funds can be routed to support NBS for water security or DRM projects: in the United States, compensatory mitigation generates $3.8 billion a year, which is then used to support restoration of watershed areas[50]. **Municipal bonds** are another useful policy driver that allow government entities to borrow money from investors and repay it over time using tax revenue or other collateral. Municipal bonds can be used to provide upfront capital quickly, which can be used as seed funding for NBS.

Federal or local public infrastructure spending as well as **disaster risk mitigation programs** can also be routed to green infrastructure strategies that help meet flood control standards, though the vast majority of these funds currently go toward conventional infrastructure.

Emerging sources of funding and financing approaches

Because NBS can sometimes address multiple development objectives, it is possible to generate multiple cash flows, thereby attracting a diverse base of investors interested in different project benefits. This includes mission-focused investors willing to tolerate higher risk or lower returns, who can leverage their investment to "de-risk" NBS investments for less confident investors. A variety of financing models has been introduced to make NBS bankable and to appeal to commercial interests. While private sector investment in NBS is still relatively small compared to public funding sources, these models are gaining momentum. They include, as follows:

- **Water Funds:** These pool money from multiple water-dependent private and public sector actors so that each small contribution enlarges the cumulative impact. There are more than 25 Water Funds in Latin America and the Caribbean that have routed about $120 million to invest in watershed management[51]. A review of 16 of these Water Funds found that 12 report regulating water flows, either to increase water availability or to reduce flood risk, as their primary objectives[52].
- **Green Bonds**: Also known as blue, climate, and environmental bonds, these make up a growing market ($157 billion in green bonds issued in 2017). The new Water Infrastructure Standard of the Climate Bonds Initiative (CBI) enables water projects—including projects that utilize green infrastructure—to be certified as green bonds. This provides an avenue for nature-based solutions to attract private financing, while also allowing cities to communicate with corporations and investors interested in green growth[53].
- **Insurance Payments for Risk Reduction:** Also known as catastrophe bonds, these provide financial protection in the event of disaster, such as intense storms and floods. In 2018, insurance brokerage Willis Towers Watson launched the Global Ecosystem Resilience Facility (GERF) to support coastal communities in the Caribbean[54]. GERF uses risk pooling and other financial instruments like catastrophe bonds, resilience bonds, grants, and loans to provide support to local communities.
- **Pay-for-success models:** Public and private lenders can utilize pay-for-success, environmental impact bonds, or conservation impact bonds, to tie payment for service delivery to the achievement of measurable outcomes. This approach rewards investors based on how well the NBS performs. One such example of said model is the DC Water Bond, discussed in more detail below.
- **Corporate stewardship models:** Corporations are increasingly realizing the importance of understanding the impact of their business on the environment and incorporating sustainable practices that improve company reputations, offset negative environmental impacts, safeguard valuable natural assets, and make businesses more profitable. One Coca-Cola program aims to provide water replenishment benefits equal to 100 percent of the water used in its global sales by 2020[53]. It first met its goal in 2015, and continues to do so through source water protection activities like watershed restoration, and through replenishment programs like improved wastewater collection and treatment[54].

EXAMPLES OF NBS IN ACTION

SEYCHELLES | Debt Restructuring for Protected Marine Areas[55]

In 2008, Seychelles defaulted on its national debt and has since sought ways to preserve its natural environment—the vital pillar of its economy and of its citizens' livelihoods—without endangering financial stability. In 2015, The Nature Conservancy and its impact-investing unit, NatureVest, brokered a deal to restructure a portion of Seychelles' debt with a debt-for-nature swap. The deal allows the government to restructure the country's debt with a mix of investments and grants, in exchange for designating one-third of its marine area as protected. The agreement frees capital streams and directs debt service payments to fund climate change adaptation and marine conservation activities that will improve the management of Seychelles coastlines, coral reefs, and mangroves[55]. This is the first time this financing technique has been used for the marine environment.

PHILIPPINES | National Fund for Climate Disasters[56]

The Philippines People's Survival Fund (PSF) is a national fund dedicated to supporting disaster risk reduction and climate change adaptation projects at the local level. The Philippine Congress enacted the PSF in 2012 in response to the country's vulnerability to climate-related disasters and the need for additional support at the community level. The government allocates $20 million of general revenue to the PSF, which can also be supplemented through the mobilization of additional funding sources like local governments or the private sector[56]. The PSF is managed by a board comprising six governmental and three nongovernmental representatives that evaluate project proposals for funding. Once approved, funds are disbursed under a memorandum of agreement with monitoring and reporting requirements. The PSF provides long-term financing streams to support projects proposed by local government units or accredited community organizations.

UNITED STATES | Pay-for-Success Model for Urban Green Infrastructure[57]

To better manage stormwater and prevent urban flooding, Washington, DC's water utility, DC Water, boldly pursued an unconventional financing structure to pay for its NBS program. DC Water utilized a performance-based or "pay-for-success" financing model issued as a 30-year, tax-exempt municipal bon[57], a contract between a public entity (i.e., DC Water) and private investors, where payment is based on measured environmental outcomes. The NBS program employs different types of hybrid infrastructure to minimize urban hazards, including bioretention or rain gardens; permeable pavements; and downspout disconnection, which reroutes drainage pipes into rain barrels or pervious surfaces[57]. This financing mechanism is the first of its kind for NBS in the United States.

Source: Nijmegen/Wikipedia

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