Technical Guidance on Nature-Based Solutions for Ports in Africa

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About this Guidance

This guidance was developed by IUCN, the International Union for Conservation of Nature, at the request of the Italian Ministry of Environment and Energy Security, the United Nations Environment Programme (UNEP),and the Organisation for Economic Co-operation and Development (OECD), to provide additional context and guidance on Nature-based Solutions (NbS) and related nature-positive interventions that can improve the climate resilience of port infrastructure. It is intended for applicants of the Nature-based Solutions Innovation Accelerator (NBS-IA) and is designed to help them understand which types of interventions may deliver meaningful climate resilience outcomes for infrastructure, and how these may be translated into innovative pilot concepts. The guidance is not intended to be prescriptive, but rather to support applicants in screening,designing, and strengthening their proposals. It also helps to distinguish between NbS, hybrid, and enabling measures, and includes 13 technical handouts on potential interventions. In addition, it introduces the IUCN Global Standard for Nature-based Solutions to help applicants identify credible, scalable, and investable solutions for resilient port systems. This guidance does not replace the Call for Proposal guidelines, nor does it replace the IUCN Global Standard for Nature-based Solutions or the self-assessment tool.


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CHAPTER 1.
Nature-based Solutions and Infrastructure

> *"Nature-based Solutions are defined as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits." —WCC 2016, Resolution 069.*

Put simply, Nature-based Solutions use the protection, restoration or sustainable management of ecosystems to address societal challenges such as climate change, biodiversity loss, and water and food insecurity, while delivering benefits for both people and nature.

BOX 1: OVERVIEW OF NBS-RELATED TERMINOLOGY

Green or natural infrastructure: Networks of natural or semi-natural ecosystems, such as wetlands, forests, and green spaces, that provide services such as water regulation, climate resilience, and biodiversity support.

Grey or engineered infrastructure: Traditional engineered structures, such as dams, pipes, seawalls, and treatment plants, designed to manage water, transport, or other services through built solutions.

Grey and green infrastructure can be combined as hybrid solutions to optimise performance and financial benefits.

IUCN has developed the Global Standard for Nature-based Solutions to guide users in designing and implementing NbS in a consistent, credible, and effective way. In addition, the Standard sets clear benchmarks for measuring the progress of NbS. The Standard provides a robust framework for the consistent and credible application of NbS and includes 8 criteria and 27 associated indicators, together with guiding questions to help users assess and improve their solution. **Figure 1** provides a rapid overview of the criteria and indicators. **Table 1** provides a rapid checklist to help applicants screen their ideas against the Standard.

BOX 2: COMPENSATORY MEASURES CANNOT CONSTITUTE A NATURE-BASED SOLUTION ON THEIR OWN

Biodiversity compensation or offset measures are not, in themselves, Nature-based Solutions. Measures implemented primarily to meet regulatory, permitting, or mitigation requirements are intended to compensate for ecological damage associated with infrastructure development or operations. However, compensatory measures associated with port expansion, dredging, shoreline works, or related coastal infrastructure can provide a starting point for the development of a broader NbS intervention. When well designed to respond to clearly identified societal challenges, support ecosystem integrity and biodiversity, and align with the IUCN Global Standard for Nature-based Solutions, such compensation measures form part of a nature-positive approach and help establish the foundations for a credible NbS intervention.

Applicants should first use the technical handouts to identify one or more interventions suited to the climate risk or operational challenge they wish to address, including innovative adaptations where appropriate, and then use Table 1 to check that the proposed solution is aligned with the key steps and considerations of the IUCN Global Standard for Nature-based Solutions.

Figure 1: IUCN Global Standard for Nature-based Solutions -second edition, (IUCN, 2025)



Table 1. Rapid screening checklist based on the IUCN Global Standard for Nature-based Solutions criteria to aid applicants in designing NbS in port and coastal infrastructure

NbS Criterion	STEP	WHAT THIS STEP IS ABOUT	WHAT NEEDS TO BE DONE
 Criterion 1 (3 indicators)	IDENTIFY A SOCIETAL CHALLENGE	Define the main climate-related or operational challenge affecting the port system, surrounding ecosystems and communities, and explain why it matters for infrastructure performance, service continuity, and costs.	• Identify the main risk or challenge affecting the port system and surrounding communities or ecosystems, such as coastal flooding, landslides, extreme heat, declining water quality, habitat degradation, or wider climate vulnerability. • Explain how this challenge affects, or could affect, port infrastructure, operations, access, safety, maintenance, or costs. • Define the geographic scale of the challenge: the port footprint, shoreline, estuary, harbour, coastal corridor, or wider catchment. • Consider upstream and downstream linkages, including sediment flows, drainage infrastructure, watershed pressures, and shoreline dynamics.
	How applicants to the NBS-IA can use this step to help structure their interventions Applicants should begin by identifying the main climate hazard or operational challenge affecting the port system and then use the technical handouts to identify one or more possible interventions. For example, if coastal flooding is the main challenge, relevant handouts may include Handout 01, 02, 03, 05, or 12. This step then helps applicants refine that choice by clarifying the scale of the problem, the implications for infrastructure and operations, and the wider system linkages that need to be taken into account.		
 Criterion 2 (3 indicators)	INCORPORATE AN ECOLOGICAL, ECONOMIC, SOCIAL, AND CULTURAL SYSTEMS PERSPECTIVE	Design the intervention with an understanding of the wider coastal, ecological, social, and economic system in which the port operates.	• Assess ecological conditions, coastal processes, land and water uses, governance arrangements, livelihoods, community interests, and cultural values linked to the site. • Identify how the proposed intervention fits within broader coastal management, land-use planning, and infrastructure planning. • Consider the wider system, including estuaries, mangroves, wetlands, dunes, reefs, fisheries, settlements, logistics corridors, and port access channels.
	How applicants to the NBS-IA can use this step to help structure their interventions Applicants should use this step to check whether the proposed intervention makes sense within the wider system in which the port operates, rather than only at the immediate project site. For example, if a port is considering a shoreline or flood-protection intervention, relevant handouts may include Handouts 01, 03, 05, 10, or 12, but the final choice should also take account of surrounding habitats, sediment movement, drainage pathways, nearby communities, and existing or planned infrastructure. This step helps applicants identify synergies, avoid unintended impacts, and show how the proposed intervention supports both infrastructure resilience and the wider coastal or landscape system.		

Criterion 3
(4 indicators)

ENSURE NBS RESULT IN POSITIVE CHANGE IN THE STATE OF BIODIVERSITY AND ENHANCED ECOSYSTEM INTEGRITY, INCLUDING CONNECTIVITY	Show that the intervention will deliver measurable improvements in biodiversity, ecosystem function, and, where relevant, ecological connectivity.	• Establish a baseline for habitats, species, hydrology, shoreline condition, and ecosystem functions. • Define measurable ecological objectives and indicators. • Show how the intervention will restore, conserve, or sustainably manage ecosystems. • Prioritise native habitats and species, and identify how the intervention supports ecosystem functions relevant to port resilience, such as wave attenuation, sediment stabilisation, flood buffering, nursery habitat, or water filtration.

How applicants to the NBS-IA can use this step to help structure their interventions

Applicants should use this step to explain how the proposed intervention delivers measurable improvements in ecosystem condition while also strengthening climate resilience and infrastructure performance. For example, relevant handouts may include Handouts 02, 03, 04, 05, 07, or 12, depending on the type of ecosystem and risk context. Applicants should therefore define a clear ecological baseline, identify measurable ecological objectives, and explain how improved ecosystem condition contributes to outcomes such as flood buffering, shoreline stability, sediment management, water-quality improvement, or habitat recovery.

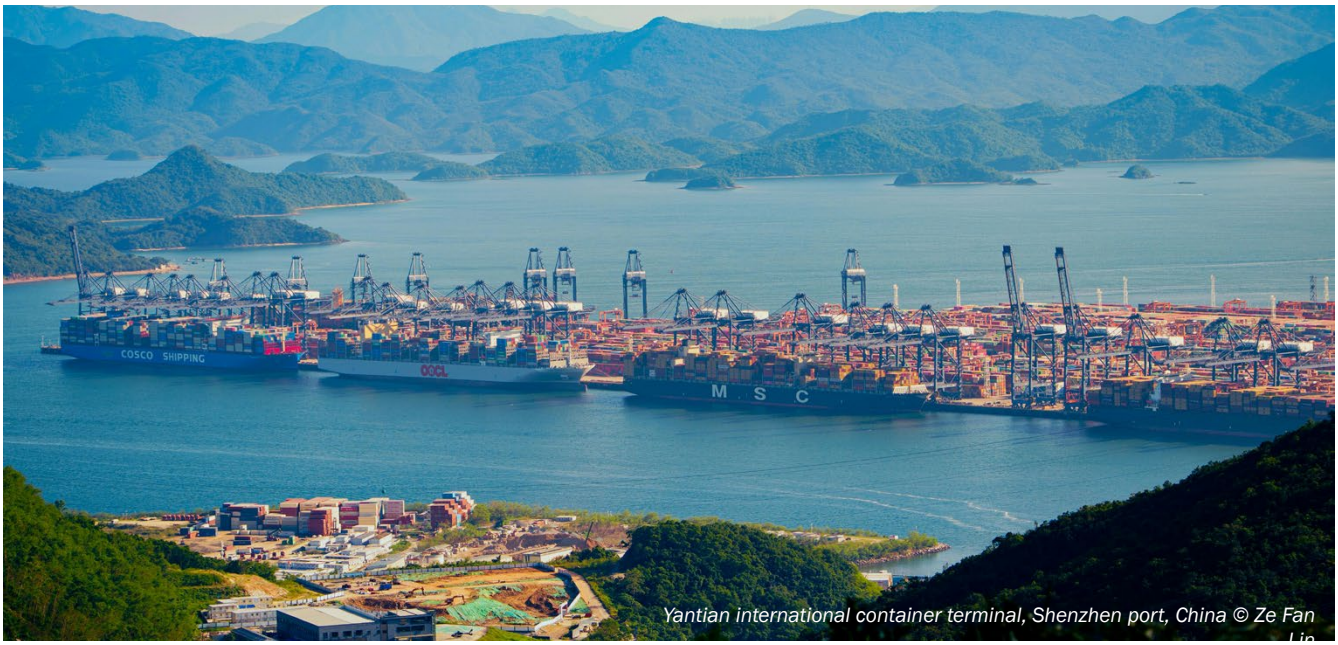
Criterion 5
(5 indicators)

Criterion 6
(3 indicators)

MOBILISE PARTNERS FOR SUCCESS	Engage relevant stakeholders early to support co-design, legitimacy, implementation, and long-term stewardship.	• Map stakeholders who influence, use, manage, or are affected by the intervention, including port authorities, terminal operators, municipalities, coastal and environmental agencies, communities, fishers, NGOs, researchers, and financiers. • Define roles, responsibilities and engagement arrangements early, including co-design and shared governance approaches.

How applicants to the NBS-IA can use this step to help structure their interventions

Applicants should use this step to clarify who needs to be involved in the intervention, and how those actors will support its design, delivery, and long-term stewardship. Early engagement can help identify local needs, reduce delivery risks, strengthen legitimacy, and support the long-term functioning of the intervention. Applicants should explain how engagement will take place during design and implementation, including how feedback, transparency, and grievance mechanisms will be addressed where relevant. They should also show how responsibilities for delivery, maintenance, and long-term stewardship will be shared or coordinated.



Yantian international container terminal, Shenzhen port, China © Ze Fan Lin

Criterion 4 (3 indicators)	ENSURE YOUR SOLUTION IS FINANCIALLY FEASIBLE AND ECONOMICALLY JUSTIFIED	Demonstrate that the intervention is investable, maintainable, and capable of delivering benefits over time.	• Estimate implementation, maintenance, monitoring, and adaptive management needs. • Identify potential financing sources and the institutions responsible for delivery and long-term management. • Assess the value of expected benefits, such as avoided erosion or flood damage, reduced maintenance costs, biodiversity gains, carbon or water benefits, and livelihood co-benefits where relevant. • Consider whole-life costs, not only upfront capital cost.

How applicants to the NBS-IA can use this step to help structure their interventions

Applicants should use this step to show that the proposed intervention is not only technically relevant, but also realistic to finance, implement, and maintain over time. This means considering both short- and long-term costs, identifying possible financing sources and delivery partners, and explaining how the intervention can reduce risks or costs over its lifetime. For port operators and developers, this may include avoided damage, reduced maintenance needs, improved asset performance, or other resilience and co-benefit gains that strengthen the case for investment.

Criterion 7 (3 indicators) Criterion 8 (3 indicators)	MANAGE NBS ADAPTIVELY	Monitor performance and adjust design or management as ecological, climatic, and operational conditions change.	• Put in place monitoring, governance, and learning arrangements that allow the intervention to be adjusted as conditions change, including in response to ecological performance, climate change, sediment dynamics, storm impacts, or stakeholder feedback. • Track both infrastructure and ecological outcomes over time.

How applicants to the NBS-IA can use this step to help structure their interventions

Applicants should use this step to show how the intervention will be monitored, reviewed, and adjusted over time as conditions change. This is particularly important in port and coastal settings, where performance may be influenced by changing climate risks, sediment dynamics, ecological response, operational pressures, or extreme events. By building adaptive management into project design from the outset, applicants can strengthen the long-term resilience, reliability, and sustainability of the proposed intervention.



Crane Machineries, Beirut port, Lebanon © Jo Kassis

CHAPTER 2.
Sustainable Port Development: The Case for Nature-based Solutions

Ports have evolved from relatively isolated loading zones into highly integrated logistics hubs that must reconcile trade growth with climate-friendly development (Pavlic et al., 2014; Belmoukari et al., 2023). As part of this evolution, port sustainability has passed through several distinct conceptual frameworks, moving from a narrow focus on operational efficiency towards more integrated models of environmental, social, and economic performance. Variations within these models exist. For example, **sustainable ports** tend to emphasise the three interrelated pillars of environmental, social, and economic sustainability; **green ports** focus on long-term, climate-friendly infrastructure development, and responsible behaviour by both port management and employees; and **smart ports** introduce digitalisation, Artificial Intelligence, and the Internet of Things (IoT) as tools to address environmental and operational challenges through real-time data-sharing and automation (Lim et al., 2019, Pavlic et al., 2014, Belmoukari et al., 2023).

Resilience has become a central concern in modern port management, emphasising the ability of the port system to maintain its functions under unexpected conditions and to recover quickly from disruption (IAPH, 2023). A shift towards nature-positive development pathways is underway, with climate adaptation increasingly viewed as an opportunity to integrate co-benefits and maximise efficiency, productivity, and restorative approaches (Dupar et al., 2023). This shift provides an entry point for considering the contribution that Nature-based Solutions can make to the future of port infrastructure.

2.1 Nature-based Solutions in the African context

Nature-based Solutions (NbS) are increasingly recognised as an important approach to strengthening climate resilience across Africa (Collins et al., 2025). Their relevance is particularly high given the continent's exposure to climate hazards such as flooding, storm surges, and heatwaves, which already result in major economic losses each year (Collins et al., 2025). In this context, NbS offer significant opportunities through coastal restoration, including mangroves, reefs, and seagrass to reduce erosion; catchment restoration to improve water regulation; and measures to reverse land degradation and stabilise soils (Dupar et al., 2023).

The uptake of NbS in Africa is supported by a growing enabling environment. Examples include high-level political commitments, such as the African Union's Agenda 2063, and the incorporation of NbS into 85% of sub-Saharan African countries' Nationally Determined Contributions (NDCs). At the implementation level, successful NbS depend on consultative, cross-sectoral planning and on integration into national adaptation policies (Collins et al.,2025; Dupar et al., 2023). Momentum is growing, with NbS project initiation increasing by approximately 15% annually between 2012 and 2022, while financing mechanisms are gradually diversifying beyond international grants to include green bonds, carbon credits, and debt-for-nature swaps (Collins et al., 2025).

Barriers to wider adoption remain, including a persistent policy preference for grey, engineered infrastructure; limited technical capacity for design, implementation, and maintenance; and data gaps that weaken hydrological and climatological modelling and, in turn, the quality of planning and risk assessment. Low financial attractiveness remains a further constraint. Social factors, including insecure land tenure and limited community involvement, also continue to hinder implementation (Collins et al., 2025). These challenges are particularly relevant in infrastructure sectors such as ports, where large-scale investments interact with complex coastal systems, multiple users, and high levels of climate exposure.

2.2 Why NbS matter for African port infrastructure

Within the African port context, Nature-based Solutions are not only environmentally desirable, but also strategically important. Ports are critical nodal links in regional and global supply chains, and disruptions caused by natural hazards or sea-level rise can generate cascading impacts across national and regional economies (IAPH, 2023). In this setting, mangrove restoration can help reduce exposure to coastal flooding and storm

surges that threaten port facilities and associated infrastructure (Dupar et al., 2023). The management and restoration of coral reefs can also help attenuate wave energy, thereby reducing coastal erosion, contributing to flood reduction, and helping protect coastal infrastructure (Beck et al., 2018).

BOX 3: DATA GAPS IN AFRICAN PORTS AND IMPLICATIONS FOR CLIMATE RISK ASSESSMENT

Climate risk assessment in African ports is often constrained by major data gaps, ranging from broad climatological and hydrological information to more granular operational, logistics, trade, and congestion data. These gaps make it more difficult to identify vulnerabilities, assess exposure, design effective interventions, and respond to immediate hazards. In resource-constrained or inaccessible settings, community-based monitoring, including forms of citizen science, can help fill some of these gaps by generating long-term environmental observations and real-time local data.

Sources: *(Dupar et al., 2023; Collins et al., 2025; World Bank, 2024; Thorn et al., 2022).*

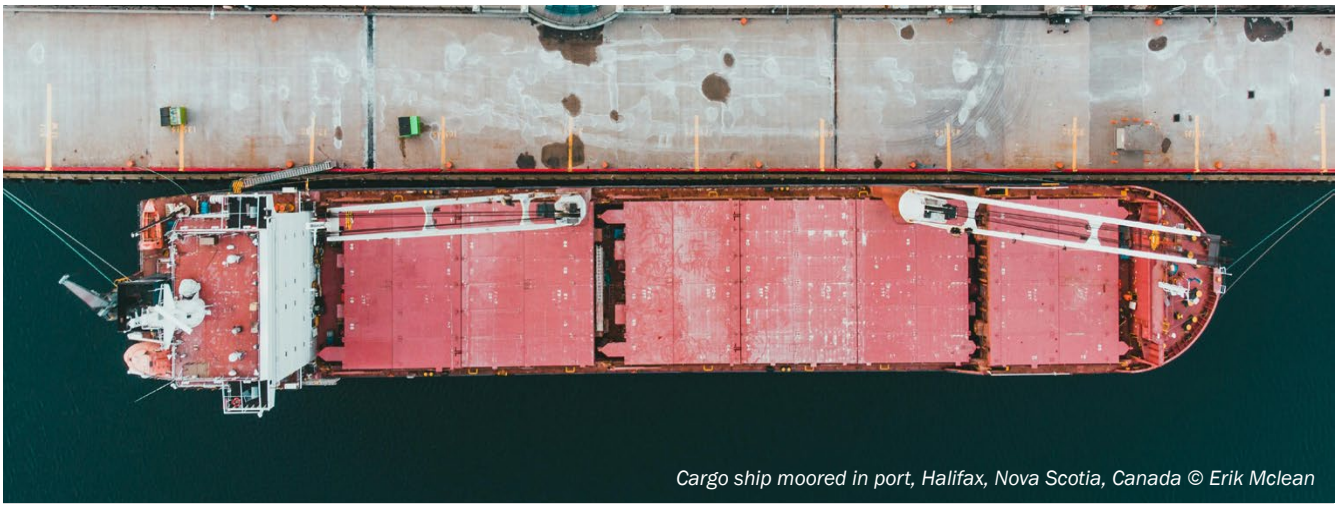
NbS are also relevant from an infrastructure-planning perspective because African infrastructure faces climate risks that are substantially higher than those in other regions, including risks estimated to be twice as high as in Latin America and five times higher than in Europe (AUC and OECD, 2025). Compared with purely hard-engineered solutions, NbS can offer greater flexibility and adaptability over time, particularly where climate and environmental conditions are changing. They can also complement existing built infrastructure by extending its life-span and improving overall performance (Dupar et al., 2023).

BOX 4: INSECURE LAND TENURE AND IMPLICATIONS FOR PORT DEVELOPMENT

Insecure land tenure can create major social risks for port and infrastructure development in Africa, including conflict over land use, involuntary displacement, disruption of livelihoods, and the exclusion of Indigenous Peoples and local communities from project benefits. These risks can delay projects, undermine legitimacy, and weaken long-term outcomes. Addressing them requires greater transparency over land rights, participatory planning, inclusive governance, and appropriate safeguards, compensation, and dispute resolution mechanisms.

Sources: *(Collins et al., 2025; Thorn et al., 2022; AUC and OECD, 2025).*

Finally, NbS align closely with wider regional ambitions for a sustainable Blue Economy. The African Union identifies port operations as a key component of this agenda, and the integration of NbS into port development can help reconcile economic growth with the objectives of Agenda 2063 for environmentally sustainable and climate-resilient economies (Dupar et al., 2023). **Boxes 3 and 4** provide an overview of typical constraints present in African ports.



Cargo ship moored in port, Halifax, Nova Scotia, Canada © Erik Mclean

CHAPTER 3.
Technical handouts on climate and infrastructure resilience

This chapter presents a practical set of technical handouts to help applicants identify, select, and combine interventions that can strengthen the climate resilience of port infrastructure and surrounding systems. The handouts were developed through an extensive review of the literature, guidance, and case-study evidence, together with the initial long list of 24 potential solutions considered for this annexe. That longer list was useful in capturing the range of possible interventions, but a number of entries overlapped, represented variations of the same intervention, or were too broad to be easily applied by applicants. To make the guidance more practical and easier to use, the 24 proposed solutions were therefore screened, consolidated, and translated into 13 technical handouts.

Each handout presents a set of interventions, its main climate-risk function, its relevance to infrastructure resilience, typical locations, the disciplines needed, direct benefits, co-benefits, investment considerations, implementation challenges, and illustrative case studies. Some handouts focus mainly on measures within or immediately adjacent to the port boundary, while others relate to wider estuarine, coastal, urban, or catchment systems that shape conditions at the port. As a result, the handouts are not intended to be an exhaustive catalogue of every possible measure. Rather, they provide a curated set of interventions that are likely to be most useful for applicants seeking to respond to climate risks in ways that are technically grounded, operationally relevant, and adaptable to local contexts.



Drone Shot of a Harbour in Mwanza, Tanzania © George John

3.1 How applicants should use the handouts

Applicants should use the handouts as practical design aids rather than as a checklist from which to select a single solution. The starting point should always be the local risk context, for example, coastal flooding, river flooding, urban flooding, shoreline instability, heat stress, or other climate-related pressures affecting the port system. From there, applicants can identify the handout, or combination of handouts that best respond to those risks.

The strongest proposals are unlikely to rely on a single measure in isolation. In many cases, resilience depends on combining interventions across scales. A port may, for example, combine beneficial reuse of dredged sediment with wetlands, mangroves, or reef-based measures to strengthen coastal protection. Likewise, runoff and flood risks within the port may require a combination of blue-green drainage infrastructure, constructed wetlands, and wider floodable storage or channel measures beyond the terminal boundary. Applicants should therefore use the handouts not only to identify individual measures, but also to think through how interventions can reinforce one another as part of a broader system.

Applicants should also be clear about the status of the proposed measure. Some handouts describe interventions that can become full Nature-based Solutions if they are designed and implemented in line with the principles set out in Chapter 1. Others describe hybrid or enabling measures that are highly relevant to climate resilience, but do not qualify as NbS on their own. This distinction is intentional. The purpose of the handouts is not to narrow the field too early, but to help applicants develop more credible and better-integrated proposals. Where a proposed intervention is hybrid or enabling, applicants should explain how it contributes to resilience and, where possible, how it can be combined with ecological measures so that ecosystem function, biodiversity, and social co-benefits are strengthened alongside infrastructure performance.

The handouts are also intended to be useful at different stages of project development. For existing ports, they may help identify retrofit measures, ecological enhancement opportunities, or ways of improving the resilience performance of already hardened or space-constrained assets. For new developments or major expansions, they may help applicants build resilience into the project from the outset through spatial planning, sediment management, habitat buffers, floodable space, and stronger integration with surrounding coastal and watershed systems.



3.2 Innovating beyond conventional coastal measures

Applicants are encouraged to use the handouts as a starting point, but not as a limit. One of the key findings from the broader review was that some of the most relevant ideas for ports do not come only from conventional coastal engineering or coastal restoration practice. Measures developed in urban, riverine, industrial, arid, and fire-prone settings can often be adapted to port environments, where they help address operational and climate-related hazards.

This is reflected most clearly in the handouts on blue-green drainage infrastructure, constructed and floating wetlands, vegetated riverbanks, and green buffers for operational and climate risk reduction. Together, these show that useful port interventions may include heat-mitigation measures from urban areas, dust- and wind-control approaches from dry landscapes, vegetated noise and nuisance buffers from transport corridors, and, in some settings, low-flammability planted buffers and ecological firebreaks relevant to wildfire risk reduction. Such measures may not always be seen as conventional coastal NbS, but they can be highly relevant where ports interface with cities, river corridors, dry hinterlands, industrial zones, or peri-urban vegetation.

At the same time, innovation should not be interpreted as importing solutions without adaptation. Any intervention considered under this call should be adjusted to the specific conditions of the port environment, including salinity, wind exposure, space constraints, contamination, navigation and safety requirements, maintenance capacity, and institutional arrangements. The strongest proposals are therefore likely to be those that combine technical realism with ecological ambition, using the handouts to identify practical options, adapt them to the local context, and show clearly how they reduce climate risks while contributing to more resilient and better-performing port systems.



Large Cargo Ship Docked at Libyan Industrial Harbor © Abdo Alshreef



© Aerial View of Dredging Barge in Venice Lagoon

TECHNICAL HANDOUT 01: Beneficial reuse of dredged sediment

Primary hazard addressed: Coastal and river flood hazards
Solution type under NBS-IA Call for Proposals**:** Hybrid

Description

Beneficial reuse of dredged sediment is the strategic placement or reuse of dredged material to reduce climate and coastal risks while supporting habitat creation, habitat restoration, or landform reinforcement.

In port contexts, this can include thin-layer placement to raise marsh elevation, sediment placement to restore intertidal or foreshore zones, and the use of dredged material to reinforce berms, levees, mudflats, islands, or shallow coastal features. This solution is particularly relevant where dredging is already part of port development or maintenance, as it allows ports to manage sediment more productively while contributing to shoreline stability, flood risk reduction, biodiversity, and the circular use of materials.

Hazards addressed

CF	RF	UF
●	●	●
LS	**WF**	**EH**
●		
WS	**CY**	
●	●	

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

Hybrid: Green–grey or ecologically enhanced engineered intervention.

Use in project lifecycle

Design, retrofit, and maintenance: Suitable for new port or coastal protection schemes, upgrades to existing shoreline or flood-protection infrastructure, and routine dredging programmes where sediment can be used more strategically.

Typical location

Port basins and navigation channels; foreshore and backshore zones; adjacent marshes, mudflats, lagoons, and intertidal areas; levees, berms, and low-lying coastal edges.

Areas of expertise needed

Coastal engineer; dredging or sediment management specialist; marine ecologist; hydrologist; port planner or infrastructure specialist; monitoring and survey specialist.

Positive impacts

Direct benefits

- Strengthens shoreline and flood protection;
- Helps reduce erosion, overtopping, and exposure of coastal and port infrastructure.

Environmental and socio-economic co-benefits

- Circular use of materials;
- Tourism and recreation, where relevant;
- Habitat creation or restoration.

Investment benefits

- Can reduce disposal and transportation costs;
- May lower long-term maintenance and protection costs;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

Potential challenges

- Sediment quality or contamination may limit reuse options;
- Benefits often require monitoring and adaptive management over time;
- Permitting and stakeholder acceptance may be complex, especially where landforms or access are affected.

IUCN recommendations

- Use dredged sediment for a defined resilience purpose, such as raising low-lying marshes, reinforcing foreshore zones, or reducing erosion pressure on exposed port edges.
- Do not use sediment placement as fill alone where there is an opportunity to support marshes, mudflats, vegetated berms, or living shorelines.
- Connect sediment reuse to a wider sediment and water system, for example through wetland creation, intertidal habitat recovery, or mangrove and seagrass measures that improve long-term stability and ecological performance.

Case studies:

1. Mud Motor, Port of Harlingen, Koehoal, Netherlands: Dredged sediment was strategically relocated to support salt-marsh development, foreshore stabilisation, and reduced sediment recirculation to the harbour.
2. Freeman Creek marsh, North Carolina, USA: Sediment was applied to low-lying marshes to build elevation and improve resilience to sea-level rise.
3. Horseshoe Bend Island, Lower Atchafalaya River, USA: Dredged sediment was used to create landforms that influence flow, shoaling, and habitat.



© Aerial View of Breakwater, Terengganu, Malaysia

TECHNICAL HANDOUT 02:
Reef-based coastal protection

Primary hazard addressed: Coastal flood hazard
Solution type under NBS-IA Call for Proposals**:** NbS centred / Hybrid

Description

Reef-based coastal protection uses living or habitat-forming reef systems to reduce wave energy, stabilise shorelines, and protect coastal assets while supporting marine habitat. In port and coastal infrastructure contexts, this can include shellfish or oyster reefs in sheltered waters, coral reef restoration in tropical marine settings, and ecological or artificial reef structures designed to work with natural processes. These solutions are particularly relevant where ports face erosion, wave exposure, or storm impacts and where nature-based or hybrid measures can complement conventional shoreline protection. Oyster reefs form hard, habitat-rich structures in coastal waters, while living breakwaters have been designed specifically to reduce coastal erosion and strengthen resilience.

Hazards addressed

CF	RF	UF
●		
LS	**WF**	**EH**
WS	**CY**	
	●	

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

NbS centred / Hybrid: May qualify as NbS if designed and implemented in line with NbS principles (refer to Chapter 1).

Use in project lifecycle

Design, retrofit, and rehabilitation: Suitable for new shoreline protection schemes, upgrades to exposed or eroding port edges, and rehabilitation of degraded nearshore habitats where reef structures can support coastal protection.

Typical location

Sheltered port edges; estuarine margins; low-energy bays; quay-fronts with suitable hydrodynamic conditions; tropical nearshore waters; seaward approaches; or port-adjacent coastal waters.

Areas of expertise needed

Coastal engineer; marine ecologist; hydrologist; port planner or infrastructure specialist; monitoring and survey specialist.

Positive impacts

Direct benefits

- Attenuates wave energy;
- Strengthens shoreline and flood protection;
- Helps reduce exposure of coastal and port infrastructure.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved water quality and filtration;
- Fisheries, education, and tourism value, where relevant.

Investment benefits

- Can reduce long-term shoreline maintenance and repair costs;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

Potential challenges

- Site suitability is critical, including salinity, wave climate, water quality, and depth;
- Shellfish and coral systems may require time to establish and mature;
- Navigation, vessel wake, and dredging pressures may constrain where reefs can be placed;
- Benefits often require monitoring and adaptive management over time.

IUCN recommendations

- Reef-based protection works best when it is not used alone. In suitable settings, combine it with living shorelines, shellfish reefs, or seagrass meadows to improve sediment stability and shoreline protection closer to the port edge.
- In tropical or low-lying coastal areas, pair reef measures with mangroves, coastal wetlands, or marshes so that offshore wave attenuation is backed up by landward flood buffering.
- Where the shoreline is already hardened, use reef-based measures alongside ecological enhancement of seawalls, revetments, or breakwaters so that protection and habitat improvement happen across the full shoreline.

Case studies:

1. Living Breakwaters, Staten Island, USA: An offshore breakwater system designed to reduce coastal erosion and strengthen physical, ecological, and social resilience along the shoreline.
2. Native Oyster Living Shoreline, San Diego Bay, USA: A native oyster reef and living shoreline project designed to protect bay tidelands and shorelines while increasing climate resilience and restoring habitat.
3. REEFolution, Kenya: Modular and 3D-printed artificial reef structures used to support coral recruitment, rebuild reef habitat, and improve coastal protection functions.



© Aerial View Virginia Salt Marsh Waterways, Virginia, United States

TECHNICAL HANDOUT 03:
Coastal wetlands and marshes for flood buffering

Primary hazard addressed: Coastal flood hazard
Solution type under NBS-IA Call for Proposals**:** NbS centred

Description

Coastal wetlands and marshes can reduce climate risks by storing water, attenuating waves, trapping sediment, and stabilising shorelines. In port and coastal infrastructure contexts, this can include restoring or creating tidal marshes, intertidal wetlands, and sheltered coastal wetland systems that help buffer storm surges, reduce flooding, and improve the resilience of low-lying coastal edges. These solutions are particularly relevant where ports are exposed to sea-level rise, overtopping, erosion, or changing sediment dynamics, and where natural or hybrid buffers can complement conventional flood-protection infrastructure.

Hazards addressed

CF	RF	UF
●	●	●
LS	**WF**	**EH**
WS	**CY**	
●	●	

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

NbS centred.

Use in project lifecycle

Design, retrofit, and adaptation: Suitable for new coastal resilience schemes, adaptation of low-lying or reclaimed land, and upgrades to existing flood-buffer landscapes where wetlands or marshes can complement engineered defences.

Typical location

Low-lying coastal fringes; estuarine edges; reclaimed land; back-of-port shorelines; former ponds or lagoons; sheltered intertidal areas adjacent to port and coastal infrastructure.

Areas of expertise needed

Coastal engineer; ecologist; hydrologist; port planner or infrastructure specialist; environmental specialist; monitoring and survey specialist.

Positive impacts

Direct benefits

- Attenuates wave energy and storm-surge impacts;
- Strengthens shoreline and flood protection;
- Helps reduce exposure of coastal and port infrastructure.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved water quality and filtration;
- Carbon storage;
- Fisheries, education, and tourism value, where relevant.

Investment benefits

- Can reduce long-term pressure on grey flood-defence assets;
- May lower shoreline maintenance and repair costs over time;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

Potential challenges

- Site suitability is critical; land availability and operational space constraints may limit options near active port areas;
- Poorly designed interventions may not keep pace with sea-level rise or may create management conflicts with drainage and access;
- Establishment can take time and may require adaptive management.

IUCN recommendations

- Do not treat the coastal wetland as an isolated feature. Strengthen exposed edges with marsh sills, vegetated intertidal fringes, or living shorelines where wave action could otherwise damage the wetland.
- Improve how water moves through the wider site by linking wetlands to floodable retention areas, overflow channels, or estuarine transition zones where space and hydrology allow.
- In suitable coastal settings, combine wetlands with mangroves, seagrass, or mudflat recovery so that flood buffering is reinforced by stronger sediment stability, habitat quality, and ecological connectivity.

Case studies:

1. South Bay Salt Pond Restoration, California, USA: A tidal wetland restoration programme that combines habitat restoration with flood-risk management and sea-level rise planning.
2. Medmerry Managed Realignment, West Sussex, UK: A coastal scheme that created new intertidal habitat while improving flood protection for homes, infrastructure, and main roads.
3. Steart Marshes, Somerset, UK: A wetland creation project developed to work with nature to protect homes and businesses from flooding while creating extensive marsh habitat.



© Rocky shoreline of the Baltic Sea, Estonia

TECHNICAL HANDOUT 04:
Seagrass meadows for seabed and shoreline stability

Primary hazard addressed: Coastal flood hazard
Solution type under NBS-IA Call for Proposals**:** NbS centred / Hybrid

Description

Seagrass meadows can reduce climate and coastal risks by trapping sediment, stabilising the seabed, attenuating wave energy, and improving water quality. In port and coastal infrastructure contexts, this can include the restoration, recovery, or expansion of eelgrass, seagrass, or Posidonia meadows in sheltered harbour waters, estuarine margins, lagoons, and other low-energy coastal zones. These solutions are particularly relevant where ports face erosion, sediment resuspension, declining water quality, or exposure of shallow coastal edges to wave action. Seagrass is widely recognised as contributing to coastal protection through its interaction with waves and sediment dynamics.

Hazards addressed

CF	RF	UF
●		
LS	**WF**	**EH**
WS	**CY**	
	●	

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

NbS centred / Hybrid: May qualify as NbS if designed and implemented in line with NbS principles (refer to Chapter 1).

Use in project lifecycle

Design, retrofit, and rehabilitation: Suitable for new coastal resilience schemes; rehabilitation of dredged or degraded shallow waters; and recovery of nearshore habitat.

Typical location

Sheltered harbour waters; estuarine margins; lagoons; shallow port-adjacent bays; low-energy coastal waters with suitable light, salinity, and water-quality conditions.

Areas of expertise needed

Coastal engineer; marine ecologist; seagrass specialist; hydrologist; port planner or infrastructure specialist; environmental specialist; monitoring and survey specialist.

Positive impacts

Direct benefits

- Attenuates wave energy and storm-surge impacts;
- Strengthens shoreline and flood protection;
- Helps reduce exposure of coastal and port infrastructure.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved water quality and filtration;
- Blue carbon storage;
- Fisheries, education, and tourism value, where relevant.

Investment benefits

- May lower shoreline infrastructure maintenance and repair costs over time;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

Potential challenges

- Success depends on light availability, water quality, sediment conditions, and hydrodynamic suitability;
- Seagrass can be vulnerable to dredging, turbidity, anchor damage, and poor water quality;
- Some sites may require substrate preparation or protection;
- Establishment and recovery may take time and often require monitoring and adaptive management.

IUCN recommendations

- Pair seagrass measures with living shorelines, shellfish reefs, or marsh fringes where additional edge protection and wave reduction are needed closer to the shoreline.
- Improve the wider setting by reducing pressures from stormwater runoff, turbidity, dredging impacts, or invasive species, so that seagrass can establish and persist more reliably.
- In suitable tropical or estuarine settings, connect seagrass recovery with mangroves, mudflats, or coastal wetlands so that sediment stability, habitat quality, and flood buffering are strengthened across the wider coastal system.

Case studies:

1. Cockburn Sound and Owen Anchorage, Western Australia: Seagrass restoration has been developed in response to historical losses linked to dredging and port infrastructure, with the aim of improving ecosystem resilience in the region.
2. San Diego Bay, USA: The Port of San Diego has supported eelgrass and blue carbon work that highlights the role of seagrass beds in habitat value, carbon storage, and wider environmental resilience in a working port bay.
3. Virginia Coastal Bays, USA: Large-scale eelgrass restoration by seeding helped recover meadow extent and contributed to broader ecosystem recovery in shallow coastal bays.



© A fisherman casting a fishing net surrounded by mangroves

TECHNICAL HANDOUT 05:
Mangroves for coastal protection and port resilience

Primary hazard addressed: Coastal flood and cyclone hazards
Solution type under NBS-IA Call for Proposals**:** NbS centred

Description

Mangroves can reduce coastal and climate risks by attenuating waves and storm surges, trapping sediment, stabilising shorelines, and buffering low-lying coastal areas. In port and coastal infrastructure contexts, this can include mangrove protection, restoration, ecological mangrove rehabilitation, and hybrid designs where mangroves are combined with supporting structures or sediment measures. These solutions are particularly relevant where ports are exposed to erosion, storm impacts, saline intrusion, or unstable muddy shorelines, and where landward infrastructure depends on the condition of intertidal coastal systems. Mangroves are widely recognised as natural coastal buffers and are also associated with blue carbon, fisheries habitat, and wider coastal resilience benefits.

Hazards addressed

CF	RF	UF
●		
LS	**WF**	**EH**
WS	**CY**	
●	●	

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

NbS centred.

Use in project lifecycle

Protection, rehabilitation, and adaptation: Suitable for conserving existing mangrove belts, rehabilitating degraded intertidal areas, and strengthening wider coastal protection strategies around ports and low-lying coastal infrastructure.

Typical location

Estuarine margins; tidal flats; sheltered muddy coasts; port-adjacent creeks and lagoons; low-lying coastal fringes; transition zones between open water and landward infrastructure.

Areas of expertise needed

Coastal engineer; restoration specialist; hydrologist; port planner or infrastructure specialist; environmental specialist; monitoring and survey specialist.

Potential challenges

- Success depends on tidal exchange, sediment conditions, salinity, and site elevation;
- Poorly planned planting in unsuitable locations can fail;
- Survival may be affected by grazing, erosion, pollution, or altered hydrology;
- Benefits usually require long-term stewardship, monitoring, and protection from ongoing disturbance.

Positive impacts

Direct benefits

- Attenuates wave energy and storm-surge impacts;
- Strengthens shoreline and flood protection;
- Traps sediment and helps reduce exposure of coastal and port infrastructure.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved water quality and filtration;
- Blue carbon storage;
- Fisheries, education, and tourism value, where relevant.

Investment benefits

- May lower shoreline infrastructure maintenance and repair costs over time;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

IUCN recommendations

- Protect or restore tidal flow and sediment supply first, so mangroves establish under the right physical conditions rather than relying only on planting.
- Where wave energy is too high, combine mangroves with sediment-based measures, permeable structures, or sheltered foreshore features so young mangroves are not exposed before they can stabilise.
- Link mangroves to adjacent mudflats, seagrass areas, wetlands, or living shorelines so that shoreline protection, habitat quality, and ecological connectivity improve together.

Case studies:

1. Kenya Ports Authority, Kwale County, Kenya: Port-linked mangrove restoration near Shimoni and Majoreni aimed at coastal protection, biodiversity recovery, and livelihood support through partnership with local communities.
2. North-eastern Viet Nam mangrove programme: Mangrove restoration and protection implemented to address the loss of coastal protection and reduce exposure to storms and flooding along vulnerable coastlines.
3. Pulau Tekong, Singapore: Mangrove restoration combined with coastal protection design on an eroding shoreline, showing how mangroves can be integrated into a wider resilience strategy in a highly managed coastal setting.



© Port on the bank of the Rio Negro River, Manaus, Brazil

TECHNICAL HANDOUT 06:
Vegetated riverbanks and channel-edge stabilisation

Primary hazard addressed: River flood and landslide hazards
Solution type under NBS-IA Call for Proposals**:** NbS centred / Hybrid

Description

Vegetated riverbanks and channel-edge stabilisation use native planting, soil bioengineering, and, where needed, light structural support to reduce erosion, stabilise banks, and improve the performance of river or drainage corridors connected to ports. In port and infrastructure contexts, this can include planted riverbanks, vegetated embankments, coir-based bank protection, brush mattresses, root wads, live staking, vetiver systems, and other bioengineered edge treatments along rivers, canals, drainage channels, and flood-conveyance corridors. These measures are particularly relevant where ports depend on river access, estuarine channels, drainage outfalls, or transport corridors that are vulnerable to bank erosion, sediment build-up, or flood damage. Soil bioengineering approaches are used to soften edges, prevent erosion, and improve the performance and resilience of waterways connected to ports.

Hazards addressed

CF	RF	UF
	●	●
LS	**WF**	**EH**
●		●
WS	**CY**	
●		

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

NbS centred / Hybrid: May qualify as NbS if designed and implemented in line with NbS principles (refer to Chapter 1).

Use in project lifecycle

Design, retrofit, and rehabilitation: Suitable for new river and drainage corridors, upgrades to eroding banks and embankments, and rehabilitation of degraded waterways that influence port access, flood conveyance, or sediment delivery.

Typical location

Riverbanks; drainage channels; estuarine tributaries; canal edges; embankments; flood conveyance corridors; transport or utility corridors.

Areas of expertise needed

Restoration specialist; hydrologist; port planner or infrastructure specialist; landscape architect; environmental specialist; monitoring and survey specialist.

Potential challenges

- Success depends on bank slope, flow conditions, soil type, and hydraulic loads;
- Poorly planned planting may fail where scour, wake, or rapid drawdown pressures are high;
- Native plants survival may be affected by grazing, erosion, pollution, or altered hydrology;
- Benefits usually require monitoring, maintenance, and protection from ongoing disturbance.

Positive impacts

Direct benefits

- Reduces local flood damage to embankments, access roads, utilities, and channel-side infrastructure;
- Stabilises eroding banks and channel edges;
- Helps reduce sediment inputs and localised bank failure.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved water quality and filtration;
- Urban heat island mitigation;
- Recreational and educational value in accessible settings.

Investment benefits

- May lower repair costs linked to bank failure and erosion over time;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

IUCN recommendations

- Use vegetated stabilisation as part of a wider river and flood-management corridor, not only as isolated bank planting.
- Combine planted banks with secondary channels, overflow areas, or floodable buffer zones where space allows, so flood conveyance and erosion control work together.
- Where rivers connect to estuaries or ports, link bank stabilisation to wetlands, marshes, or estuarine transition zones so that reduced erosion also supports habitat quality and downstream resilience.

Case studies:

1. River Rhine, Worms, Germany: Technical-biological bank protection was installed specifically to deal with hydraulic loads from inland navigation while improving ecological performance.
2. Bishan–Ang Mo Kio Park, Kallang River, Singapore: A concrete canal was redesigned into a naturalised river using plants, bioengineering, and civil works while maintaining flood-conveyance and drainage functions.



© Eco-concrete breakwater structures

TECHNICAL HANDOUT 07:
Ecological enhancement for hardened assets

Primary hazard addressed: Coastal flood and cyclone hazards
Solution type under NBS-IA Call for Proposals**:** Hybrid

Description

Ecological enhancement of hardened assets uses nature-inclusive retrofits or redesigned armour units to improve the ecological performance of existing seawalls, revetments, quay walls, breakwaters, pilings, and rock armour while maintaining their infrastructure function. In port contexts, this can include living seawalls, eco-concrete, habitat tiles, piling wraps, floating or hanging habitat structures, and ecologically enhanced armour units. These solutions are particularly relevant where ports already depend on hard coastal infrastructure but want to improve resilience, reduce local scour and edge instability, and deliver biodiversity and water-quality co-benefits without major changes to the operational footprint.

Hazards addressed

CF	RF	UF
●		
LS	**WF**	**EH**
WS	**CY**	
	●	

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

Hybrid: Green–grey or ecologically enhanced engineered intervention.

Use in project lifecycle

Retrofit, upgrade, and design: Suitable for improving existing hardened edges, replacing ageing revetments or armour, and integrating ecological features into new quay walls, seawalls, or breakwaters where ports need to maintain structural performance.

Typical location

Existing seawalls; revetments; quay walls; breakwaters; armour units; pilings; jetties; pontoons; sheltered marinas; and calm inner basins.

Areas of expertise needed

Coastal engineer; structural or civil engineer; marine ecologist; port planner or infrastructure specialist; materials specialist; monitoring and survey specialist.

Potential challenges

- Ecological enhancement depends on site conditions such as tidal range, water quality, exposure, and colonisation potential;
- Not all retrofits deliver meaningful resilience benefits unless they are integrated with the wider shoreline design;
- Some solutions may add complexity to installation, maintenance, or permitting;
- Habitat features can underperform if placed in unsuitable hydraulic or operational conditions.

Positive impacts

Direct benefits

- Attenuates wave energy and storm-surge impacts;
- Reduces local flood damage to embankments, access roads, utilities, and channel-side infrastructure;
- Traps sediment and helps reduce exposure of eroding banks and channel edges.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved water quality and filtration in some settings;
- Urban heat island mitigation;
- Recreational and educational value in accessible settings.

Investment benefits

- Can extend the lifetime of grey infrastructure;
- May reduce long-term repair or retrofit costs linked to bank failure and erosion over time;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

IUCN recommendations

- Use retrofits where they also support a clear resilience purpose, such as improving the performance of revetments, reducing scour, or strengthening the adaptation of existing edges.
- Combine hardened-edge enhancement with living shorelines, shellfish reefs, seagrass meadows, or marsh fringes where conditions allow, so that ecological retrofit is backed by wider shoreline processes.
- Link retrofits to a broader waterfront strategy, for example better stormwater quality, invasive-species management, or restoration of adjacent shallow habitats, so that habitat uplift is not confined to isolated hard surfaces.

Case studies:

1. Port of San Diego, USA: ECOncrete Coastalock units were installed as single-layer coastal armour to provide structural shoreline support while creating native habitat and supporting climate adaptation of port assets.
2. Living Seawalls, New South Wales, Australia: Habitat panels were retrofitted onto existing seawalls to create micro-habitats for marine life while supporting adaptation of defended urban shorelines to sea-level rise.
3. Hong Kong Eco-shoreline Guideline, CEDD (2023): Guidance on integrating eco-engineered features into artificial shorelines, including seawalls and rip-rap structures, to improve habitat diversity and ecological performance while maintaining engineering function.



© Water canal, Hsinchu City, Taiwan

TECHNICAL HANDOUT 08:
Stormwater management and blue-green drainage infrastructure

Primary hazard addressed: Urban flood and water scarcity hazards
Solution type under NBS-IA Call for Proposals**:** NbS centred / Hybrid

Description

Stormwater management and blue-green drainage infrastructure use vegetated or permeable features to slow, store, filter, and direct runoff in ways that reduce local flooding and improve water quality. In port and infrastructure contexts, this can include bioswales, rain gardens, permeable surfaces, green roofs, native revegetation, and connected drainage corridors designed to work with soils and vegetation rather than relying only on pipes and hard drainage. These measures are particularly relevant where ports face intense rainfall, surface flooding, runoff pollution, and pressure on existing drainage systems.

Hazards addressed

CF	RF	UF
	●	●
LS	**WF**	**EH**
		●
WS	**CY**	
●	●	

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

NbS centred / Hybrid: May qualify as NbS if designed and implemented in line with NbS principles (refer to Chapter 1).

Use in project lifecycle

Design, retrofit, and upgrade: Suitable for new terminals, roads, yards, and buildings, as well as retrofits to existing paved areas, parking areas, drainage corridors, and administrative zones where runoff and heat are already a problem.

Typical location

Port roads; yards; parking areas; building edges; roofs; drainage outfalls; administrative compounds; logistics parks; and other paved or flood-prone operational areas.

Areas of expertise needed

Civil or drainage engineer; landscape architect; hydrologist; port planner or infrastructure specialist; environmental specialist; monitoring and survey specialist.

Positive impacts

Direct benefits

- Attenuates runoff and storm-surge impacts;
- Reduces local flood damage to embankments, access roads, utilities, and channel-side infrastructure;
- Traps sediment and helps reduce disruption to roads, yards, access routes, and operational areas.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved air and water quality;
- Urban heat island mitigation;
- Recreational and educational value in accessible settings.

Investment benefits

- Can extend the lifetime of grey infrastructure;
- May lower repair, pumping, and drainage-maintenance costs over time;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

Potential challenges

- Heavily contaminated runoff or constrained industrial sites may limit infiltration options;
- Green roofs and permeable pavements may require structural or maintenance checks before installation;
- Without maintenance, planted systems can clog, lose storage capacity, or perform poorly.

IUCN recommendations

- Treat blue-green drainage infrastructure as a connected site system, not as scattered green features. Link bioswales, rain gardens, green roofs, and permeable areas into a connected drainage strategy with clear storage, overflow, and discharge logic.
- In low-lying or highly paved port areas, combine these measures with constructed wetlands, retention basins, or floodable buffer areas where additional storage is needed.
- Where runoff enters coastal or estuarine waters, connect drainage measures to wetlands, marsh fringes, or vegetated outfalls so that flood reduction is reinforced by better water quality and habitat performance.

Case studies:

1. Port of Corpus Christi, Texas, USA: A network of bioswales and rain gardens collects runoff from roofs, parking, and paved areas in a coastal industrial setting.
2. Southwest Resiliency Park, Hoboken, USA: Rain gardens, bioswales, and permeable pavement were integrated into a flood-protection park to help manage stormwater and reduce flood risk.
3. Greenpoint Industrial Area, New York City, USA: A green infrastructure plan for an industrial waterfront district that uses bioswales, permeable surfaces, and detention-based systems to manage runoff and strengthen stormwater resilience.



© Wooden path in Denver Wetlands, Colorado, USA

TECHNICAL HANDOUT 09:
Constructed and floating wetlands

Primary hazard addressed: Urban flood and water scarcity hazards
Solution type under NBS-IA Call for Proposals**:** NbS centred / Hybrid

Description

Constructed and floating wetlands use planted wetland systems to slow, store, and treat runoff while improving the resilience of drainage networks, retention areas, and sheltered waterfronts. In port and infrastructure contexts, this can include constructed stormwater wetlands, treatment wetlands at outfalls, wetland retention ponds, and floating wetland systems installed in basins, canals, or other space-constrained waters. These measures are particularly relevant where ports face intense rainfall, local flooding, polluted runoff, or limited room for land-based green infrastructure.

Hazards addressed

CF	RF	UF
	●	●
LS	**WF**	**EH**
WS	**CY**	
●	●	

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

NbS centred / Hybrid: May qualify as NbS if designed and implemented in line with NbS principles (refer to Chapter 1).

Use in project lifecycle

Design, retrofit, and upgrade: Suitable for new stormwater and flood-management schemes, upgrades to existing drainage outfalls and retention areas, and retrofits to sheltered basins or constrained waterfront spaces where runoff treatment and flood storage are both needed.

Typical location

Drainage outfalls; retention ponds; detention basins; canal edges; sheltered inner basins; low-lying port-adjacent land; urban waterfronts; runoff collection points.

Areas of expertise needed

Civil or drainage engineer; ecologist; hydrologist; port planner or infrastructure specialist; environmental specialist; monitoring and survey specialist.

Potential challenges

- Heavily contaminated runoff may require pre-treatment or more controlled wetland design;
- Floating wetlands are not a substitute for full flood storage where large volumes are involved;
- Constructed and floating wetlands can underperform if poorly connected to the drainage network or if sediment build-up is not managed.

Positive impacts

Direct benefits

- Attenuates runoff and storm-surge impacts;
- Reduces local flood damage to embankments, access roads, utilities, and channel-side infrastructure;
- Traps sediment and helps reduce disruption to roads, yards, access routes, and operational areas.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved air and water quality;
- Carbon storage;
- Urban heat island mitigation;
- Recreational and educational value in accessible settings.

Investment benefits

- Can reduce the need for larger downstream grey drainage infrastructure;
- May lower repair costs linked to drainage systems over time;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

IUCN recommendations

- Size the wetland for the actual runoff and storage function required. Small treatment wetlands and floating wetlands can improve water quality, but they do not replace larger storage areas where flood volumes are high.
- Match the design to the runoff type and pollutant load. Where runoff is heavily contaminated, include pre-treatment or sediment traps so the wetland does not clog or underperform.
- Protect long-term function through maintenance, sediment management, and vegetation management, especially at inlets, outlets, and overflow points.

Case studies:

1. The Emerald Tutu, East Boston, USA: A floating wetland prototype designed for coastal storm protection, water-quality improvement, and ecosystem benefits in a constrained waterfront setting.
2. Freshwater Wildlife Conservation Park, Phu Quoc, Viet Nam: A hybrid flood-management concept centred on a multifunctional wetland park, assessed as an alternative to conventional river dredging and widening in a high-risk urban flood setting.
3. Putrajaya Wetlands, Malaysia: A large constructed freshwater wetland system designed for stormwater treatment, flood control, and water-quality improvement before water enters Putrajaya Lake.



© Dunes landscape on Amrum Island, Germany

TECHNICAL HANDOUT 10:
Sandy shoreline and dune buffers

Primary hazard addressed: Coastal flood hazard
Solution type under NBS-IA Call for Proposals**:** NbS centred / Hybrid

Description

Sandy shoreline and dune buffers use sand, dunes, vegetated backshore, cobble berms, and other soft or dynamic shoreline features to reduce wave impacts, store sediment, and protect landward infrastructure. In port and coastal infrastructure contexts, this can include beach nourishment, dune creation or reinforcement, dune planting, upper beach berms, and other sediment-based buffers that help reduce overtopping and erosion on exposed shorelines. These solutions are particularly relevant where ports, access roads, utility corridors, or low-lying coastal land sit behind sandy or mixed-sediment shorelines and need protection that can adjust over time.

Hazards addressed

CF	RF	UF
●		
LS	**WF**	**EH**
WS	**CY**	
	●	

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

NbS centred / Hybrid: May qualify as NbS if designed and implemented in line with NbS principles (refer to Chapter 1).

Use in project lifecycle

Design, retrofit, and adaptation: Suitable for new coastal resilience schemes, reinforcement of exposed sandy shorelines, and upgrades to existing low-lying frontages where dynamic sediment buffers can complement, or reduce pressure on, grey infrastructure.

Typical location

Exposed sandy shorelines; backshore and foredune areas; low-lying coastal frontages; dike fronts; port-adjacent beaches; causeway or access-road edges; reclamation margins with suitable sediment conditions.

Areas of expertise needed

Coastal engineer; ecologist; hydrologist; port planner or infrastructure specialist; environmental specialist; monitoring and survey specialist.

Positive impacts

Direct benefits

- Attenuates wave and storm-surge impacts;
- Strengthens shoreline and flood protection;
- Helps reduce erosion, overtopping, and exposure of coastal and port infrastructure.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved water quality;
- Recreational and educational value in accessible settings.

Investment benefits

- Can reduce long-term pressure on grey infrastructure;
- May lower repair and maintenance costs over time;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

Potential challenges

- Poorly placed sand can erode quickly or fail to support dune growth;
- Highly constrained operational port edges may limit where sandy buffers are practical;
- Newly created systems may need monitoring and periodic maintenance.

IUCN recommendations

- Use sandy buffers where there is enough space and sediment movement for the beach or dune to function as a dynamic protection feature.
- Match the design to the local shoreline type, including wave climate, sediment size, dune growth potential, and overtopping risk.
- Where landward assets are important, connect beach and dune measures to a wider protection system, for example wetlands, upper beach berms, dikes, or low-lying flood buffers.

Case studies:

1. The Sand Motor, the Netherlands: A sand nourishment placed offshore to maintain and reinforce the coastline by allowing natural forces to spread sand along the coast and into the dunes, contributing to long-term coastal safety.
2. Prins Hendrik Sand Dike, Texel, Netherlands: A sand reinforcement in front of the existing sea dike, used to improve flood protection while creating beaches, dunes, mudflats, and salt marshes.
3. Cardiff State Beach Living Shoreline, California, USA: A living shoreline intended to provide sea-level rise and flood protection by reducing beach erosion and restoring dune systems that buffer coastal flooding and protect critical infrastructure.



© The Port of Hamburg, located on the River Elbe, Germany

TECHNICAL HANDOUT 11:
Floodable buffer areas and flow optimisation

Primary hazard addressed: River flood hazard
Solution type under NBS-IA Call for Proposals**:** NbS centred / Hybrid

Description

Floodable buffer areas and overflow channels create extra space for water during high-flow events, reducing pressure on embankments, drainage systems, transport corridors, and other low-lying infrastructure. In port and infrastructure contexts, this can include controlled flood-storage areas, overflow basins, secondary channels, flood bypasses, widened floodplains, and set-back embankments that allow water to spread safely rather than concentrating flood peaks in confined channels. These measures are particularly relevant where ports depend on river access, estuarine corridors, or low-lying hinterland connections that are vulnerable to flooding, backwater effects, or drainage overload.

Hazards addressed

CF	RF	UF
●	●	●
LS	**WF**	**EH**
WS	**CY**	
	●	

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

NbS centred / Hybrid: May qualify as NbS if designed and implemented in line with NbS principles (refer to Chapter 1).

Use in project lifecycle

Design, retrofit, and adaptation: Suitable for new flood-management schemes, adaptation of low-lying port-adjacent land, and upgrades to existing embankment, drainage, and access systems where additional flood-storage or bypass capacity is needed.

Typical location

Floodplains; river margins; estuarine corridors; low-lying land between embankments and infrastructure; port-adjacent open land; drainage basins; transport corridors crossing flood-prone land.

Areas of expertise needed

Coastal engineer; hydrologist; geomorphologist; port planner or infrastructure specialist; ecologist; landscape architect; monitoring and survey specialist.

Potential challenges

- Requires enough land or corridor width for water to spread safely;
- Success depends on hydraulic design, inlet and outlet control, and how the scheme interacts with existing embankments and structures;
- Land-use change, ownership, and stakeholder acceptance can be difficult, especially where land is already intensively used;
- Poorly integrated schemes may shift flood risk rather than reduce it.

Positive impacts

Direct benefits

- Attenuates storm-surge impacts;
- Enhances flood-flow control;
- Protects low-lying infrastructure, access roads, utilities, and nearby settlements.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved water quality;
- Recreational and educational value in accessible settings.

Investment benefits

- Can reduce long-term pressure on grey infrastructure and the need to keep raising embankments;
- May lower long-term flood-damage and recovery costs;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

IUCN recommendations

- Use these measures where there is a clear hydraulic role, such as reducing peak levels, diverting extreme flows, or protecting low-lying access and utility corridors.
- Make sure the scheme has a defined relationship with embankments, spillways, inlets, and drainage infrastructure.
- Connect floodable areas and bypass channels to wetlands, estuarine transition zones, or restored floodplain habitats, so that flood management is reinforced by stronger landscape function rather than relying on storage alone.

Case studies:

1. Alkborough Flats, Humber Estuary, United Kingdom: A managed flood-storage and spillway scheme in the Humber estuary, a major commercial estuary linked to the ports of Hull, Immingham, and Goole. It was developed to support long-term flood defence in an estuary facing sea-level rise and more extreme surge conditions.
2. Scheldt estuary, Antwerp, Belgium: A long-term flood-protection programme for the Scheldt system that combines flood-control areas, levees, quays, and nature development to reduce flood risk in a major tidal-river and port region.



© Tugboat and cargo Barge on the Huangpu River,Shanghai, China

TECHNICAL HANDOUT 12:
Restoring connectivity and land–sea transition zones

Primary hazard addressed: Coastal flood hazard
Solution type under NBS-IA Call for Proposals**:** NbS centred / Hybrid

Description

Estuarine connectivity and land-sea transition measures reconnect tidal flows, improve the exchange between freshwater and saltwater systems, and restore the space where rivers, wetlands, mudflats, marshes, and coastal edges interact. In port and infrastructure contexts, this can include controlled tidal exchange, reconnecting embanked land to estuarine processes, restoring transition zones between hard infrastructure and intertidal habitat, lowering or setting back embankments, and creating managed transition areas that reduce hydraulic pressure on the wider estuary. These measures are particularly relevant where ports depend on estuarine channels and low-lying hinterlands that are vulnerable to storm tides, backwater flooding, erosion, and loss of natural buffering capacity.

Hazards addressed

CF	RF	UF
●	●	●
LS	**WF**	**EH**
WS	**CY**	
●	●	

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

NbS centred / Hybrid: may qualify as NbS if designed and implemented in line with NbS principles (refer to Chapter 1).

Use in project lifecycle

Design, retrofit, and adaptation: Suitable for estuary-wide resilience strategies, adaptation of embanked or reclaimed land, upgrades to tidal flood-management systems, and restoration of transition zones around port approaches and estuarine infrastructure.

Typical location

Estuarine margins; embanked lowlands; reclaimed land; tidal rivers; port hinterlands; creek mouths; transition zones between flood defences and intertidal habitat.

Areas of expertise needed

Coastal engineer; ecologist; hydrologist; port planner or infrastructure specialist; environmental specialist; monitoring and survey specialist.

Potential challenges

- Land availability, land ownership, and stakeholder acceptance can be major constraints;
- Salinity, sedimentation, and ecological development may take time to stabilise after reconnection;
- Requires careful hydraulic design so tidal exchange improves resilience rather than transferring risk;
- Poorly designed schemes can underperform if inlet, outlet, or embankment controls are not well matched to local estuarine conditions.

Positive impacts

Direct benefits

- Attenuates river and storm-surge impacts;
- Strengthens shoreline and flood protection;
- Helps reduce erosion, overtopping, and exposure of coastal and port infrastructure.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved water quality;
- Recreational and educational value in accessible settings.

Investment benefits

- Can reduce long-term pressure on grey infrastructure;
- May lower repair and maintenance costs;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

IUCN recommendations

- Use these measures where there is a clear estuarine function, such as reducing storm-tide pressure, restoring tidal storage, or reconnecting embanked land to controlled estuarine exchange.
- Make sure sluices, inlets, outlets, and embankments are designed to manage both flood safety and ecological exchange, rather than focusing on one objective only.
- Link these measures to a broader estuarine system, for example mudflats, marshes, wetlands, overflow areas, or managed flood-storage zones, so that transition zones support both infrastructure resilience and ecosystem recovery.

Case studies:

1. Port Clarence and Greatham South, Tees Estuary, United Kingdom: A flood alleviation and habitat-creation scheme in an industrial estuary that replaced ageing defences, protected residents and businesses, and created new estuarine habitat as part of the wider Tees tidal flood-risk strategy.
2. Lippenbroek controlled reduced-tide scheme, Belgium: A pilot regulated tidal exchange project developed to test whether a flood control area with controlled reduced tides could deliver both flood defence and the development of intertidal marsh and mudflat functions.



Industrial cranes, Tauranga port, New Zealand © Robert So

TECHNICAL HANDOUT 13:
Green buffers for operational and climate risk reduction

Primary hazard addressed: Extreme heat hazard
Solution type under NBS-IA Call for Proposals**:** NbS centred / Hybrid

Description

Green buffers use vegetation strategically to reduce exposure to heat, dust, wind, noise, and, in some settings, wildfire. In port and infrastructure contexts, this can include tree belts, shelterbelts, vegetated berms, shrub windbreaks, green façades, planted setbacks, and low-flammability planted strips along terminal perimeters, haul roads, logistics yards, storage areas, rail edges, and interfaces with nearby communities. These measures are particularly relevant where hard, exposed, and highly paved operational areas create heat build-up, wind-blown dust, nuisance impacts, or fire exposure along the urban–industrial edge.

Hazards addressed

CF	RF	UF
		●
LS	**WF**	**EH**
	●	●
WS	**CY**	
●		

CF = Coastal flood hazard
RF = River flood hazard
UF = Urban flood hazard
LS = Landslide hazard
WF = Wildfire hazard
EH = Extreme heat hazard
WS = Water scarcity hazard
CY = Cyclone hazard

Solution type

NbS centred / Hybrid: May qualify as NbS if designed and implemented in line with NbS principles (refer to Chapter 1).

Use in project lifecycle

Design, retrofit, and adaptation: Suitable for new industrial layouts, retrofits to exposed operational edges and adaptation of road, rail, and utility corridors where nuisance reduction and climate resilience are needed.

Typical location

Terminal perimeters; logistics yards; roadsides; rail edges; open storage areas; building frontages; community–industrial interfaces; dry and windy edges of port or industrial estates; peri-urban and wildland–urban interface zones.

Areas of expertise needed

Landscape architect; environmental specialist; ecologist; fire-risk specialist; civil or drainage engineer; port planner or infrastructure specialist; monitoring and maintenance specialist.

Potential challenges

- Performance depends heavily on species choice, spacing, maturity, maintenance, and exposure conditions;
- Poorly placed vegetation can interfere with visibility, security, utilities, or operational clearance zones;
- In saline, polluted, or drought-prone settings, standard urban planting palettes may fail;
- Buffers intended for wildfire reduction require active design and maintenance, not just planting;
- Green roofs and façades may require structural checks, irrigation, or specialist maintenance.

Positive impacts

Direct benefits

- Attenuates runoff and storm-surge impacts;
- Reduces local flood damage to embankments, access roads, utilities, and channel-side infrastructure;
- Traps sediment and helps reduce disruption to roads, yards, access routes, and operational areas.

Environmental and socio-economic co-benefits

- Habitat creation and biodiversity gains;
- Improved air and water quality;
- Improved working conditions;
- Urban heat island mitigation;
- Recreational and educational value in accessible settings.

Investment benefits

- Can reduce heat-related disruptions and associated costs;
- May improve access to climate, biodiversity, or blended finance (e.g. GCF, GEF), where risk-reduction and habitat benefits are demonstrated.

IUCN recommendations

- Use green buffers where they solve a specific exposure problem, such as heat on paved yards, dust along haul roads, nuisance impacts at site boundaries, or fire exposure at the urban or landscape edge.
- Match the planting design to the actual operating environment, including salinity, wind, drought, contamination, sightlines, and maintenance access.
- In fire-prone settings, design buffers as managed low-flammability systems, not simply as tree planting, and combine them with fuel management, access planning, and water availability where needed.

Case studies:

1. Greenpoint Industrial Area, New York City, USA: A green infrastructure plan for an industrial waterfront district that uses street trees, green walls, green roofs, permeable systems, and detention-based bioswales to reduce runoff while also delivering noise reduction and urban heat island benefits.
2. Guardian green firebreaks, Riba-Roja de Túria, Spain: A wildfire-resilience project using low-flammability planted strips, shrub windbreak barriers, prescribed irrigation, and forest management to reduce heat, ash, wind, and fire spread near settlements and infrastructure.
3. Radvanice and Bartovice, Ostrava, Czech Republic: A case study in two locations affected by emissions from nearby industrial areas and a waste landfill, where proposed greenery was assessed for its ability to improve air-pollution conditions in exposed urban–industrial settings.

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