Flood Risk in Humanitarian Settlements: Compendium of Mitigation Measures

ETH zürich

SPUR
Spatial Development and Urban Policy

GENEVA TECHNICAL HUB

Co-convened by

UNHCR
The UN Refugee Agency

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

Flood Risk in Humanitarian Settlements: Compendium of Mitigation Measures

Flood Risk in Humanitarian Settlements: Compendium of Mitigation Measures

Spatial Development and Urban Policy, SPUR
ETH Zurich - Institute for Spatial and Landscape Development
Bruna Rohling, David Kostenwein, Mona Gairing, David Kaufmann

Geneva Technical Hub, co-convened by UNHCR and SDC
Ammar Al-Mahdawi, Emilie Schmid, Eric Bardou

External Experts
Mrudhula Koshy, Diego Bermúdez, Jonathan Parkinson

Layout and Drawings
Santiago Beaumé, Paola Pabón

Cite as
Rohling, Bruna; Kostenwein, David; Gairing, Mona; Al-Mahdawi, Ammar; Schmid, Emilie; Bardou, Eric; Kaufmann, David (2023) Flood Risk in Humanitarian Settlements: Compendium of Mitigation Measures. Zürich: ETH Zürich, UNHCR. DOI: 10.3929/ethz-b-000645680

SPUR
Spatial Development and Urban Policy

Co-convened by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

Acknowledgment

The Compendium of Mitigation Measures for Flood Risk in Humanitarian Settlements has been developed in close collaboration between UNHCR, the Swiss Development Cooperation (SDC), and ETH Zurich through the Geneva Technical Hub. While the research group Spatial Development and Urban Policy (SPUR) of Prof. Dr. David Kaufmann at ETH Zurich took the lead in developing the compendium, the work received invaluable support from various collaborators. In this regard, we would like to thank Ammar Al-Mahdawi, UNHCR, as the leader of this project. Moreover, we gratefully acknowledge the support of our UNHCR focal points and project coordinators Emilie Schmid and Eric Bardou. We also received invaluable input from Prof. Dr. Adrienne Grêt-Regamey, Chair of Planning Landscape and Urban Systems (PLUS) at ETHZ, and our external experts, Mrudhula Koshy, Diego Bermúdez, and Jonathan Parkinson. We would like to thank our graphic designers, Santiago Beaumé Pantoja and Paola Pabón, for the drawings and layout of this compendium, as well as André Eißer and his team from dotwerkstatt Berlin for building this online platform. We are also grateful for the support of the EAWAG Sandec team around Christoph Lüthi and Dorothee Spuhler for generously sharing their experience with building humanitarian compendiums. Finally, we thank all the other individuals, including our students from ETH Zurich, who have provided their input to this compendium: Cara Tobin, Elise Van Middelem, Erasmus Mseleku, Hazem Hreisha, Laura Schalbetter, Lara Sieger, Nadia Carlevaro, Nfamara K. Dampha, Philbert Mwumvane and all UNHCR settlement/shelter officers testing and improving the project, Philippe Reymond, Simon Landauer.

Executive summary

As of mid-2022, there are an estimated 103 million forcibly displaced people worldwide (UNHCR 2022). This number is expected to rise due to the changing climate, with refugee camps likely to expand. At the same time, the intensity and frequency of natural hazards, including flood events, are on the rise. Refugee settlements face a particular risk from such disruptive events due to their precarious built environment, socio-economic situation, and often remote and/or flood-exposed locations. Managing the risk of natural hazards becomes essential to ensure sustainable and safe settlements.

In the face of these challenges, UNHCR and the Swiss Development Cooperation (SDC) collaborate with the Humanitarian Planning Hub of the SPUR Research Group and the Chair of Planning Landscape and Urban Systems (PLUS) at ETH Zürich through the Geneva Technical Hub. The project provides an innovative toolbox for flood risk mitigation in refugee settlements. The toolbox comprises three integrative parts:

1. A participatory risk mapping methodology, valuing and using local knowledge while fostering cooperation and synergies with local actors.

2. An easy-to-use GIS tool (Add-in) to create flood risk maps next to operational and practical risk mitigation strategies for refugee settlements.

3. An (online) compendium of flood risk mitigation measures alongside technical drawings and context-specific good practices that are adequate for refugee settlements.

The present compendium aims to support UNHCR field staff, partners, and other practitioners with an overview of risk mitigation measures against flooding in humanitarian settlements. The selection of measures and the structure of the present compendium do not intend to prioritize certain interventions but encourage to combine various measures. The compilation can be accessed via an online compendium (www.humanitarian-risk.org) with possible printing in PDF format.

The compendium comprises two main parts. Part A introduces the document structure, the applied criteria, and the research methodology, in addition to the key topics and principles used in the compendium. Every measure listed in this compendium has been classified based on a set of criteria which can also be selected in the risk mitigation strategy tool (GIS Add-in). The criteria help to choose the measures considered most appropriate for the different contexts and flood events in refugee settlements. The compendium builds on the concept of integrated risk management, which focuses on preparing for, responding to, and recovering from natural hazards. However, the measures listed in this compendium focus mainly on the phases before a flood event, including the prevention, reduction, mitigation, adaptation, and preparedness for flood hazards. While floods comprise several different types, this compendium and the GIS Add-in focus on pluvial, riverine, and coastal floods.

Part B is the core of the compendium and presents the measures in a systematic way based on five main categories. The first category focuses on solutions for water flow management, while the second highlights interventions concerning surface water management in humanitarian settlements. The third category explores measures of adaptation of buildings and other assets against flood events. The fourth category addresses nature-based measures that apply nature restoration to mitigate flood hazards. Finally, the fifth category introduces non-structural processes, including capacity building and the participation of the refugee community at risk to reduce casualties in the case of flood events in humanitarian settlements.

The compendium has been developed based on a systematic literature review alongside the consultation of experts in the field of flood risk mitigation and from the humanitarian sector. The experts supported the development of this compendium by providing general inputs on the topic, recommending literature, and executing iterative reviews.

Table of Contents

A. Introduction

1. Compendium framework

1.1. Goal and structure of the compendium

The overall goal of the compendium is to support the UNHCR field staff with an overview of flood risk mitigation measures applicable in refugee settlements. Mitigation measures address the phase prior to a possible or expected natural or human-induced hazard. To reduce the flood risk in refugee settlements, this practical guide introduces 22 interventions alongside technical drawings and good practices from informal or humanitarian contexts. The selection of measures and the compendium's structure do not intend a prioritization of interventions. Instead, combining various complementing measures is encouraged to ensure the most effective risk mitigation. Part B of the compendium comprises the five key categories of the measures:

- Water Flow Management (Category I)
- Surface Water Management (Category II)
- Adaptation of Buildings and Other Assets (Category III)
- Nature Restoration (Category IV)
- Non-Built Measures and Capacity Building (Category V)

The consecutive numbering of the individual measures [1] - [22] links to the numbers used in the risk mitigation strategy tool (GIS Add-in) that can be applied in combination with the compendium.

1.2. Classification of the mitigation measures

To support selecting the most adequate measures for a specific local context and flood event, each measure has been classified based on a set of criteria. These are shown in the form of a table for each measure and are also used in the risk mitigation strategy tool (GIS Add-in). Most criteria come with a selection of sub-criteria. For example, the first criterion ("Type of intervention") allows the selection of the four sub-criteria ("engineered, nature-based, hybrid, non-structural"). These criteria and sub-criteria include:

Criteria	Sub-criteria
Type of Intervention	[Engineered, Nature-based, Hybrid, Non-structural]
Scale of Intervention	[Shelter-Plot-Block, Settlement, Supra-settlement]
Materials	[Not defined]
Environmental Impact	[Not defined]
Targeted Natural Hazard	[Pluvial Flood, Coastal/Riverine Flood]
Targeted Vulnerable Assets	[Buildings, Transport, Technical Infrastructure, Land Cover]
Strategy Type	[Relocate, Reduce Hazard Magnitude, Reduce Asset Vulnerability, Reduce Casualties]
Implementation Time	[Short (1 day - 1 month), Medium (1 month - 1 year), Long (> 1 year)]
Effect Duration	[Short-term (<1 year), Medium-term (1 year to 10 years), Long-term (>10 years)]
Investment Costs	[Low, Medium, High]
Maintenance Costs (yearly)	[Low (<10% investment costs), Medium (10-50%), High (>50%)]

The meaning of the sub-criteria is further explained in the following sections.

Type of intervention

a. Engineered: Engineered measures describe constructed, physical, and artificial structures.

b. Nature-based: Nature-based solutions apply nature in urban, coastal, and rural landscapes. Inspired and supported by nature, they draw on the services provided by ecosystems, also called ecosystem services or nature's contribution to people. These measures mitigate hazard events through the restoration or conservation of ecosystems, which simultaneously fosters the overall biodiversity and the ecosystem's capacity to adapt to climate change. Nature-based solutions can be applied from small to large scales.

c. Hybrid: Hybrid measures describe the combination of engineered and nature-based approaches. Although the benefits of stand-alone engineered and nature-based solutions for hazard risk reduction can meet the required needs, their combination can complement the weaknesses of the other structures and are highly recommended for allowing to cover the full spectrum of the hazard magnitudes.

d. Non-Structural: Non-structural measures comprise solutions for hazard risk management that are non-tangible. They may include the capacity building or participation of the population at risk, spatial planning and policies, or planning the relocation of parts of or an entire humanitarian settlement. The combination of non-structural with structural measures allows for covering a large spectrum of hazardous event magnitude.

Scale of intervention

a. Shelter-Plot-Block: Interventions at the shelter and block levels describe installations of a comparatively small scale that address private features (e.g., shelters, household (HH) latrines) and semi-public areas (e.g., pathways, water points, washing areas, communal latrines).

b. Settlement: Interventions at the settlement level are of medium size and cover large parts or the entire area of the settlement. They help to protect the circulation network within the settlement, the technical infrastructure (e.g. drinking water networks and sources, wastewater networks, electricity networks and power stations, or waste management areas), and the public facilities (e.g. for health, nutrition, education, culture, administration, or logistics). Finally, they protect natural and open public areas within the settlement perimeter, including communal gardens, trees, and market areas.

c. Supra-Settlement: Interventions that address the supra-settlement scale operate to mitigate the risk upstream and/or downstream of a settlement. They have an effect, alongside the settlement itself, on neighboring communities and infrastructures of regional importance. This includes access roads and bridges ensuring continued accessibility, technical infrastructures providing basic services, and public facilities such as hospitals, schools, or administrative institutions, among others. Finally, interventions at the supra-settlement level address the surrounding agricultural lands as well as sensitive ecological areas (e.g., forests, wetlands, nature reserves, upstream and downstream areas).

Environmental impact

The environmental impact of mitigation measures implies its negative or positive effect on the local environment. It contains information about, for example, the CO_2 footprint of the measure, its direct damage to the surrounding biodiversity, habitats and ecosystems, or about the material use consumption. In many cases, inadequate waste disposal, deforestation and

The environmental impact of mitigation measures implies its negative or positive effect on the local environment. It contains information about, for example, the CO_2 footprint of the

The targeted hazard

a. Pluvial Flood: Pluvial or stormwater floods take place due to heavy rainfall events. When occurring in urban or built environments, water tends to inundate streets and lower floors. This type of flooding is often aggravated by non-existing or saturated drainage systems. Compared to other floods, pluvial floods occur frequently and are of short duration (See 2.3).

b. Coastal/Riverine Flood: Riverine (or fluvial) floods take place when the water body of a river surpasses its capacities and overflows. That is mainly due to heavy rainfall over a long time but also due to large woody debris, ice jams, and snowmelt from remote areas. Riverine floods are apt to long-lasting inundation of the affected lands (See 2.3).

Coastal floods inundate dry, low-lying landscapes with seawater. The main causes of coastal floods are hurricanes, storm surges, tsunamis, high tides, or a combination of these weather events. In general, coastal flood events tend to have a severe impact (See 2.3).

The targeted vulnerable assets

Vulnerable assets are elements in refugee settlements that are likely to suffer in case of a flood event. They face damage and affect humans, infrastructures, and ecosystem services while constraining social, economic, and operational processes.

a. Buildings: Vulnerable assets listed under "Buildings" include residential shelters (individual or collective) and public services (health facilities and nutrition centers, administrative and security buildings (police), distribution centers and warehouses, educational facilities like schools, cultural/community facilities, including centers for people with specific needs, among others).

Open spaces that incorporate important social, organizational, or economic functions (e.g. gathering spaces, spaces used for recreation, social events, religious functions, and markets) are part of the criterion "Buildings". Any other built or non-built spaces that are deemed a vulnerability by local staff and the refugee community may be added to this description.

b. Transport: Vulnerable assets listed under "Transport" include transport infrastructure for internal and external mobility (Internal roads and walkways, access roads, and bridges). Access roads (and related bridges) are of utmost importance in refugee camps as large quantities of substantial goods are "imported" from outside. Walkways may also serve as a safe route for evacuation against natural or human-induced hazards.

c. Technical Infrastructure: Vulnerable assets listed under "Technical Infrastructure" include water and sanitation facilities and networks, drainage systems, and communication infrastructure. Particularly critical infrastructures include power stations and grids, and water storage (such as tanks). Any other infrastructure that is deemed a vulnerability by local staff and the refugee community may be added.

d. Land Cover: Vulnerable assets listed under "Land Cover" include land uses that are important from socioeconomic and environmental perspectives. These include agricultural land, tree cover and protection forests, and sensitive ecological areas. Any other land covers that are deemed a vulnerability by local staff and the refugee community may be added.

Strategy type

The strategy types referred to in this compendium describe the key function or goal of each measure (see Fig. 01). These four key functions comprise a) the full or partial relocation of a refugee settlement, b) the reduction of the hazard magnitude, c) the reduction of the asset vulnerability, and d) the reduction of casualties.

a. Relocate: The strategy type "relocate" shifts an entire settlement or parts thereof to another location. Components of this strategy include settlement planning or zoning. For example, a possible intervention in the context of relocations is to add buffer zones (see Category V).

b. Reduce Hazard Magnitude: The reduction of the hazard magnitude addresses pluvial, riverine, and coastal floods alike. The components of this strategy involve the inundated areas and the ones covered with sediments. Possible measures include the diversion of floods (see Category I), surface water management (see Category II), or nature restoration (see Category IV).

c. Reduce Asset Vulnerability: This strategy type aims at the reduction of asset vulnerabilities and addresses public and private assets. Possible measures are related to surface water management and drainage systems (see Category II) or the adaptation of buildings and other assets (see Category III).

d. Reduce Casualties: The reduction of casualties involves components such as hazard forecasts, awareness raising, and ensuring escape routes and safe areas (see Category V). That leads to measures such as (the teaching of) early warning systems or building safe community shelters.

Implementation time

The implementation time describes how long it takes to implement the structural measures or to prepare the non-structural interventions.

a. Short implementation processes take place within a day up to a month.

b. Medium implementation processes take place within a month up to a year.

c. Long implementation processes require longer than a year.

Effect duration

The effect duration of an intervention describes how long it is likely to last (with regular maintenance). In the case of non-structural measures, it may define the length of a procedure.

a. Short-term actions and processes last for up to 1 year.

b. Medium-term actions and processes last from 1 year to a decade.

c. Long-term actions and processes last for more than a decade.

Investment costs

The investment costs refer to the financial resources needed for the development and implementation of the measures. Given the high contextuality of costs, they are estimated based on diverse good practices. Note that the cost of a measure highly depends on the quantities implemented.

a. Low: Low-cost interventions comprise affordable actions or procedures.

b. Medium: Medium-cost interventions comprise actions or procedures that require financial resources within a reasonable range.

c. High: High-cost interventions comprise actions or procedures that are highly cost-intensive.

Yearly maintenance costs

The maintenance costs of the measures refer to the yearly financial resources that are needed for their regular assessment and maintenance once the measure has been installed.

a. Low: Low-cost maintenance refers to costs that are lower than 10% of the overall investment costs for the intervention.

b. Medium: Medium-cost maintenance refers to costs that make up between 10% and 50% of the overall investment costs for the intervention.

c. High: High-cost maintenance refers to costs that require more than 50% of the overall investment costs for the intervention.

1.3. Methods

The compendium has been developed based on a systematic literature review alongside the consultation of experts.

Literature review

The goal of the review was to identify globally applicable measures alongside good practices from local contexts similar to refugee settlements. The academic and desktop research aimed to find a mix of structural and non-structural measures, ranging from engineered, nature-based and hybrid to procedural interventions that differ based on their technical complexity, scale, building materials, affordability, and timeframe.

Consultation of External Experts

Experts in flood risk mitigation and from the humanitarian sector supported the development of this compendium in two stages. First, they backed the selection of keywords for the literature search, provided inputs into the topic, and recommended literature as the starting point for the desk research. Second, the experts evaluated and cross-checked the findings during the literature search process and iteratively reviewed the results of the compendium.

Decision tree for the strategy type of risk mitigation measure

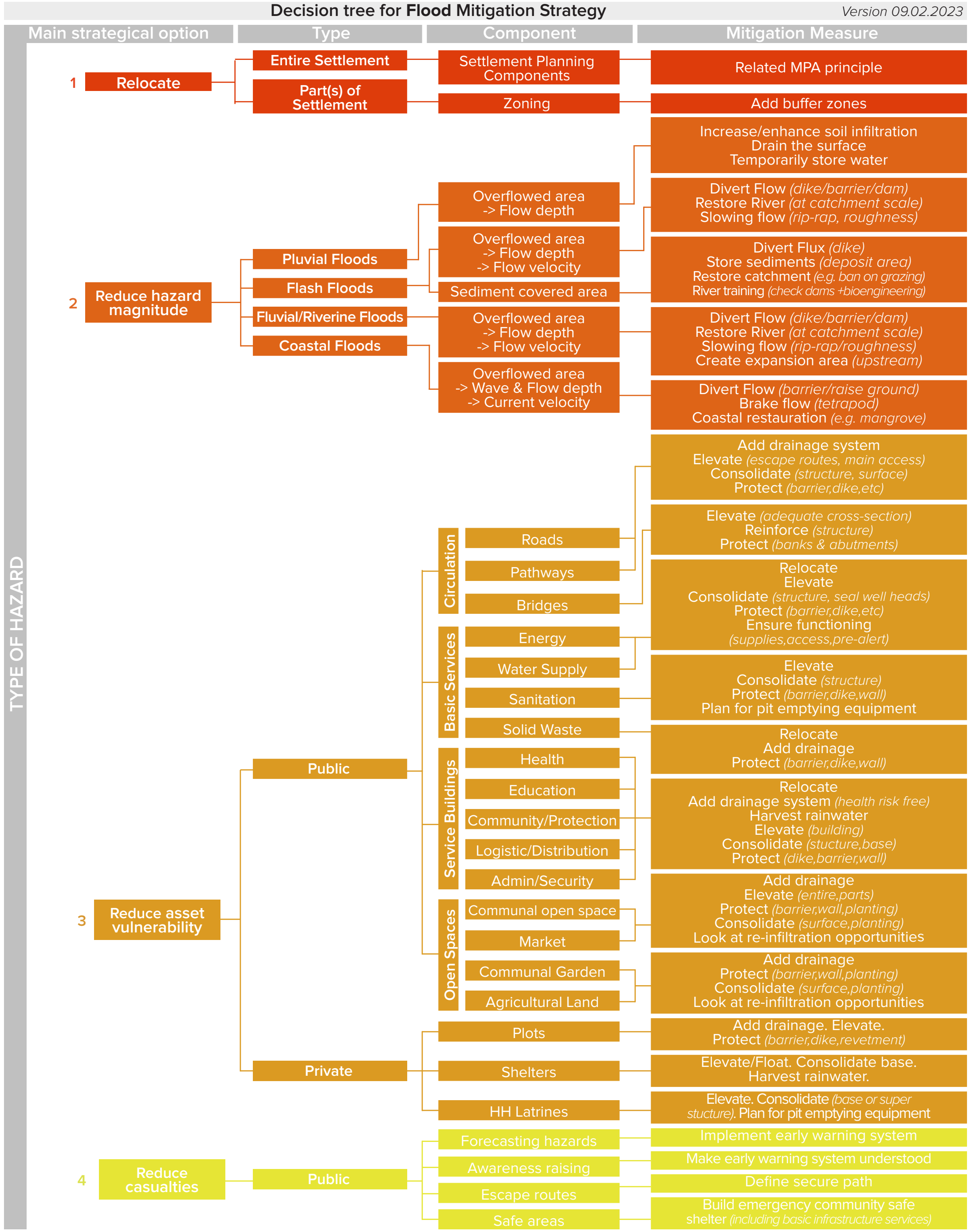


Fig. 01: *Decision Tree for Flood Mitigation in UNHCR Refugee Settlements. Emilie Schmid and Nadia Carlevaro, UNHCR 2023.*

2. Key topics and principles

2.1. Spatial planning and natural hazard management

Spatial planning plays an essential role in natural hazard management by deciding upon present and future land uses. In this light, land use plans, building permits, hazard maps, and iterative risk assessments are key planning instruments to tackle natural hazards in refugee settlements. As part of the land use plans, hazard maps can define endangered zones to determine adequate measures against natural hazards. The maps aggregate the intensity (low, medium, high) of hazards with their frequency (return period: e.g., every 10, 50, or 100 years) in the form of a matrix.

Spatial Planning at the Block and Settlement Level

At the block level of a humanitarian settlement, there are three key planning components to consider for flood risk reduction:
1. Semi-public open spaces
2. Community cluster designs
3. Private measures for plots and shelters

At the settlement scale, another three planning components are essential for flood risk reduction:
1. Transportation areas (also: Circulation areas)
2. Public open spaces
3. Public facilities

Main mitigation measures addressing the block and settlement level include:
1. The management of surface water and drainage systems (see Category II)
2. The elevation, consolidation, and protection of plots, areas, and assets (see Category III)
3. The planning of escape routes and community refuges (see Category V)
4. The relocation of plots or the entire settlement (see Category V)
5. Zoning and the creation of buffer zones (see Category V)

2.2. Flood hazards and risks

A natural hazard refers to a weather event that can lead to physical and environmental damage, injuries, the loss of lives and/or socioeconomic resources. Around one-third of natural hazards happening around the globe are flood-related and count the highest number of economic losses compared to other natural hazards.

As part of the hydro-meteorological hazards, flooding is strongly linked to the hydrological cycle (see 2.3). The cycle includes (a) the evapotranspiration back into the air, (b) the shallow infiltration into the soil, (c) the deep infiltration into the ground, and (d) the runoff from water bodies. However, the changing climate and global warming result in more energy in the Earth's system. As a result, higher evaporation and the formation of clouds with more moisture content develop. The evaporation and clouds trigger high intensity, long, and/or frequent precipitation, which increases flooding.

The combination of the hazard's characteristics, exposure, and vulnerability defines the risk of a natural hazard. The more exposed the people, ecosystems, or physical assets are to the hazard, the more their vulnerability increases and the higher the general risk. The characteristics of a flood hazard include the flood type, its intensity, depth, return period, duration, speed of runoff, and rapidity of onset. Floods do not occur in regular intervals, can hit with a sudden force (e.g., flash floods), or develop over weeks. In this light, floods need to be understood and approached as a multi-hazard phenomenon. That is because they often combine several flood types (see 2.3) and tend to provoke coupled effects such as intense precipitation triggering landslides.

2.3. Flood hazard types (selection)

Floods are part of the hydrological sub-group of natural hazards. They comprise manifold types such as coastal, riverine, flash flood, ice jam, pluvial (stormwater), groundwater, estuarine, ponding, surface water, snowmelt, and glacial lake outburst flooding. This compendium and risk mitigation strategy tool focuses on pluvial, riverine, and coastal floods, as introduced below (see Fig. 02).

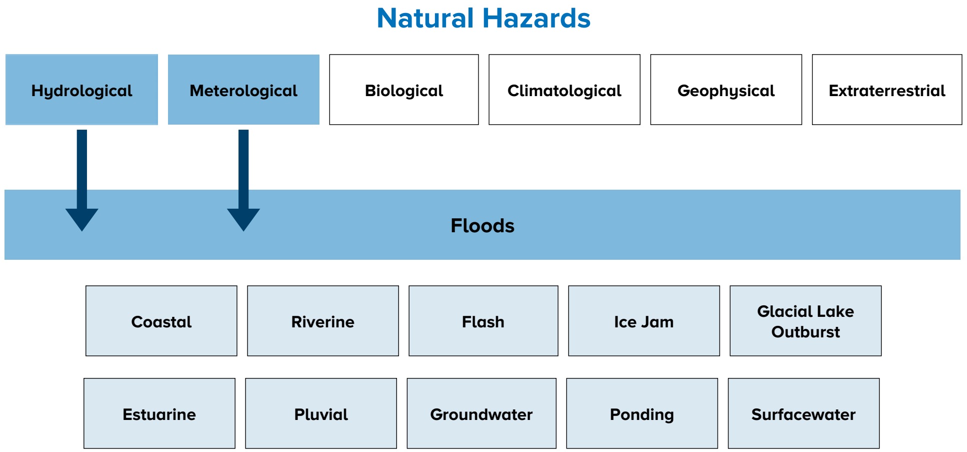


Fig. 02: *Overview of Natural Hazards and Flood Hazard Types. By the authors, 2022 based on UNISDR 2017 and APFM 2017.*

Pluvial Floods

Pluvial or stormwater floods develop due to heavy rainfall events and the lack of infiltration in the soil. They are not linked to the overflow of a particular water body, such as a lake or river. When occurring in urban or built environments, pluvial floods are often aggravated by non-existent or saturated drainage systems. Compared to other floods, pluvial floods show high frequencies and are usually of short duration, which can affect the local society and economy.

Riverine Floods

Riverine (also: fluvial) floods occur when the water body exceeds its hydraulics capacities. That is mainly due to heavy rainfall over a long time, but also snow melt or ice jam can induce this increase in flow height. The inundation of the affected lands can last for weeks and months. Due to their potential spatial extension, riverine floods can affect large areas and cause extensive socio-economic losses.

Coastal Floods

Coastal floods inundate dry, low-lying landscapes with seawater. The main causes of coastal floods are tsunamis, hurricanes, storm surges, and high tides. A combination of these events is also possible. The characteristics of coastal floods are generally of severe impact, often involving “large depths, flow velocities, and waves” (APFM 2017, p.4) and, except for hurricanes, tend to take place with short warning phases. Particularly coastal floods induced by tsunamis and hurricanes tend to have a high fatality rate.

2.4. The integrated disaster risk management cycle

To prevent or reduce the potential damages caused by natural hazards in and around refugee settlements, a continuous assessment of risk-related spatial plans and measures is needed. The integrated risk management cycle has proven a beneficial framework for spatial planning in the context of flood hazards. As a result, this compendium draws on the concept of Integrated Disaster Risk Management (IRM). Risk management seeks to enhance security from hazardous events. The process becomes integrated when it considers and combines measures for all three phases of the iterative IRM cycle:

1. Preparedness
2. (Immediate) Response
3. (Long-term) Recovery

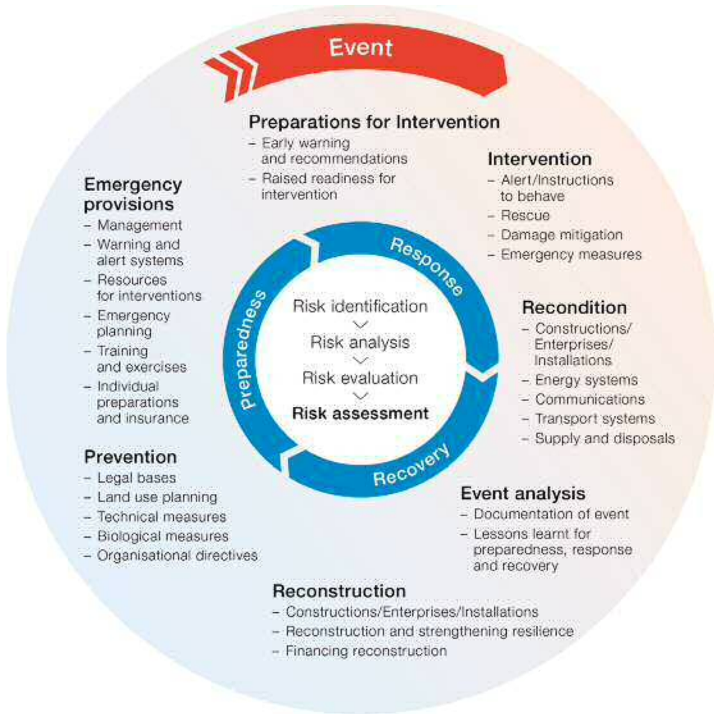


Fig. 03: *Iterative Cycle of Integrated Risk Management. Swiss Federal Office of Civil Protection (FOCP) 2019.*

Overall, the IRM cycle implies an iterative process. This means that, once the hazardous event has happened, the cycle starts anew based on continuous risk monitoring and adaptation. The idea of the cycle represents a shift in risk management during the past decades: Instead of focusing on the recovery and response during and after an event, the focus today lies more on preparedness, mitigation, and prevention. However, it also considers lessons learned in spatial planning based on disasters that have already occurred (e.g., concerning the adequacy of risk maps).

Another essential part of IRM is the dialogue and participation of all stakeholders responsible for planning and implementing adequate measures at all phases. Although this is often not possible in the context of humanitarian settlements, risk reduction strategies and the implementation of adequate measures should be displayed at all levels, from national to municipal entities. In this context, general guidelines on disaster risk management should be decided on the national and regional level to inform city or settlement master plans. At the municipal level, the land use plans then address the landowners and distinguish between building and non-building areas.

Preparedness and mitigation

Preparedness programs and measures seek “to reach an appropriate level of readiness to respond to any emergency situation that might arise” (APFM 2017, p.9). The term ‘mitigation’ as used for this compendium refers also to the phase prior to a hazardous event. The 2014 IPCC’s Fifth Assessment Report (WGII AR5) defines mitigation as the “lessening of the potential adverse impacts of physical hazards [...] through actions that reduce hazard, exposure, and vulnerability” (IPCC 2014, p. 1769). To avoid confusion, there is another understanding of mitigation coming from the field of climate change policy and referring to “the reduction of greenhouse gas emissions that are the source of climate change” (UNDRR 2020). According to the IRM cycle, the preparedness phase includes prevention based on land use planning, technical and nature-based measures, and organizational processes. The preparedness phase also comprises emergency provisions such as early warning systems, capacity building, or individual preparations.

Response

The response phase refers to the immediate actions taken in the face of a hazardous event, respectively before, during, and the period directly after an event. The goal is to meet basic needs, improve health, and save lives during an emergency until there is time and access to more comprehensive solutions that are part of the recovery phase.

Recovery

The recovery phase takes place after the hazard has occurred and left its imprint. This phase is about repair, restoration, and reconstruction of livelihoods, ecosystems, and infrastructures. In addition, recovery comprises the analysis of the hazard event to formulate lessons learned in terms of better prevention and preparedness for future events and the reduction of vulnerabilities. The goal of this phase is to provide the local communities and environment the resources to “to regain a similar or preferably a better standard as before the event” (Kreibich et al. 2015, p.968).

B. List of mitigation measures

Summary: Score Cards of Risk Mitigation Measures

No.	Measure	Environmental Impact	Risk Protection	Durability	Affordability
[01]	Engineered Dams	2	2	3	**1** (incl. high maintenance)
[02]	Vernacular and Non-engineered Dams	2	2	1	2
[03]	Geotextile Tubes and Containers	3	2	2	3
[04]	Bank Protection (Rip Rap)	2	3	3	2
[05]	Seawalls and Groynes	1	2	3	**1** (incl. high maintenance)
[06]	Drainage Systems (natural and low-tech)	3	2	2	3
[07]	Drainage Systems (high- and medium-tech)	2	3	3	2
[08]	Bioswales and Infiltration Basins	3	1 or 2	2	3
[09]	Rainwater Harvesting and Retention Basins	3	2	2	3
[10]	Permeable Ground and Pavement	3	1	2	2
[11]	Elevated Architecture	3	3	2	2
[12]	Amphibious Constructions	2	2	2	**2** (incl. high maintenance)
[13]	Consolidation of Structures	2	2	1	2
[14]	Temporary Flood Barriers	2	1	1	3
[15]	Green Roofs and Walls	3	1	2	2
[16]	Wetlands	3	2	3	2
[17]	Tree Planting and Forest Preservation	3	2	3	2
[18]	Sand Dune Management and Restoration	3	2	2	2
[19]	Floodplain Restoration	3	2	3	1
[20]	Relocation and Buffer Zones	1	3	3	1
[21]	Preparedness and Awareness Raising	3	2	2	3
[22]	Risk Mapping and Participatory Planning	3	3	3	3

Lowest / negative scores	1
Middle scores	2
Highest / positive scores	3

Scoring Examples:
“3/3 Environmental Impact” indicates no significant impact;
“3/3 Risk Protection” indicates high protection;
“3/3 Durability” indicates long-lasting measures;
“3/3 Affordability” indicates low costs/high cost-efficiency.

I. Water flow management

Introduction and summary: Water flow management

Measures related to water flow management aim to reduce the magnitude of a flood by diverting or decelerating the flow of water. They spread the flow peak. The constructions can be built upstream or downstream of the place to protect, thus limiting the amount of water arriving to the settlement. They can also be implemented along the banks of a water body to avoid overflow, erosion and possible landslides.

Infrastructure for water flow management can be temporary flood protections (*see Measure [14]*) or permanent constructions. The structures can be engineered as well as non-engineered, including vernacular and naturally occurring solutions. This chapter will present six possible measures:

1. Engineered dams (*see Measure [01]*)
2. Vernacular and non-engineered dams (*see Measure [02]*)
3. Geotextile tubes and containers (*see Measure [03]*)
4. Banks protection (Riprap) (*see Measure [04]*)
5. Retention walls (*see Measure [05]*)
6. Seawalls and groynes (*see Measure [06]*)

In general, the combination of engineered with non-engineered and nature-based interventions is strongly recommended to ensure their most effective mitigation impact.

01 | Engineered dams

Environmental impact	2/3
Risk protection	2/3
Durability	3/3
Affordability	1/3

Intro

Dams, dikes, and levees are engineered structures with an impervious core (which in most cases makes the difference with vernacular dams) that support flood control and the protection of built and agricultural areas. They are usually located along or across rivers, deltas, or seashores *(see Measure [06])*.

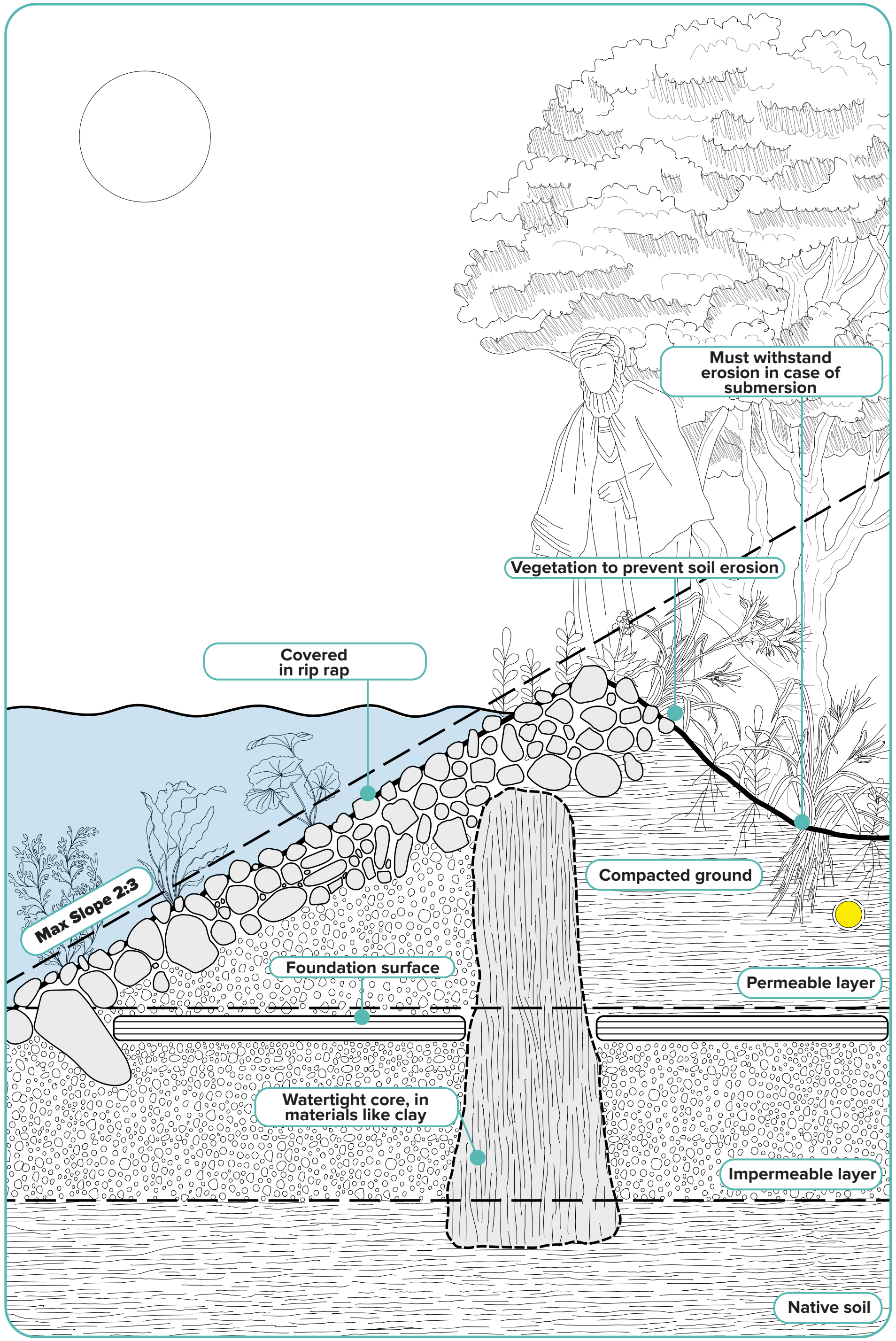
Dams
Dams represent engineered, mostly large barriers for water control, storage, and supply during times of drought. Dams can also impound other liquids, such as wastewater. They come often with complex control systems *(e.g., spillways or control gates)*. This compendium does not refer to dams for hydroelectricity production.

Dikes and levees
The main purpose of dikes and levees *(also: embankments)* is to act as a barrier for diverting, redirecting, or confining flood waters. In contrast to dams, dikes and levees usually do not have complex water control mechanisms. There are also non-engineered types of dikes and levees that do not have an impervious core *(see Measure [02])*. The impervious core, which is built deeper than the dike base, aims at avoiding the water infiltration trough the soil. The crest and the inner wall must be designed *(at least in some strategic places)* to withstand the submersion, avoiding a total collapse of the dike during a flood. Moreover, geotextile containers and tubes come increasingly into use as a hybrid form of embankment or to support the structure of dams, dikes, or levees *(see Measure [03])*. Note that the goal of the dike contradicts the drainage necessities *(see Measure [07])* and therefore must be carefully designed.

Check Dams
Check dams represent a simpler type of dams and describe barriers across channels or rivers. They aim to reduce erosion and sediment accumulation, as well as to fix the stream axis during a flood event. However, in contrast to other dams and dikes, check dams continuously operate and do not only come into effect during flood events. Wooden structures and gabion retention walls can also be used as check dams *(see Measure [05])*.

Benefits and Risk

In general, the construction of dams, dikes and levees should consider the effects of the changing climate and the linked hydrological events. The failure of a dam could cause severe floods. To ensure the safety of dams, it is crucial to apply structural, operative, and emergency planning. Large and concrete dams need comparatively strong monitoring and maintenance. As a result, the risk of failure can be higher regarding smaller dams due to sometimes neglected maintenance and design standards.



Good practice

Dike construction along the White Nile, South Sudan
Heavy rains caused severe floods and resulted in the collapse of a dike along the White Nile in 2021. The incident left the South Sudanese town of Bor in the east of the White Nile wetlands devastated. Most of the town's residents lost their homes and agricultural fields. As a response, the works involved the youth of Bor to fix around 90 spots along the dike with sandbags. In addition, a new dike of 9.4 km has been constructed with the help of excavators while the existing embankments have further been reinforced. Lastly, community-based disaster risk management committees were formed that received training in emergency preparedness and were equipped with response toolkits (Loyce 2021).

Forestry Blog (2023)
Different Types of Check Dams & Design Procedures. Available online at https://forestryblog.com/different-types-of-check-dams/.

Loyce, Nabie (2021)
Construction of Dike Brings Hope to Flood-Affected Communities in Bor. IOM South Sudan. Available online at https://southsudan.iom.int/stories/construction-dike-brings-hope-flood-affected-communities-bor, updated on 9/29/2023:55:10.

Martinez, Maria; Bakheet, Ramez; Akib, Shatirah (2021)
Innovative Techniques in the Context of Actions for Flood Risk Management: A Review. In Eng 2 (1), pp. 1–11. DOI: 10.3390/eng2010001.

Ward, Philip J.; Ruiter, Marleen C. de; Mård, Johanna; Schröter, Kai; van Loon, Anne; Veldkamp, Ted et al. (2020)
The need to integrate flood and drought disaster risk reduction strategies. In Water Security 11 p. 100070. DOI: 10.1016/j.wasec.2020.100070.

Overview of Criteria

Type of intervention:
Engineered.

Scale of Intervention:
Settlement, Supra-settlement

Materials:
1. Concrete, Rock, Earth-Fill, Timber, Gravel, Sand, Steel (Selection for Dams)
2. Earth-Fill, Compacted Soil, Wood, Sand, Clay, Concrete, Timber, Steel, Rocks, Gravel, Riprap (Selection for Dikes and Levees)

Environmental Impact:
Depending on the scale, type, and location of a dam/dike/levee, the structure can cause the loss of ecosystems and habitats, submersion of large areas of land, the disruption of natural water flows and quality, and the fragmentation of river systems.

Targeted Natural Hazard:
Coastal / Riverine Flood.

Targeted Vulnerable Assets:
Buildings, Transport, Land Cover.

Strategy Type:
Reduce Hazard Magnitude.

Implementation Time:
Long (> 1 year).

Effect Duration:
Long-term (>10 years).

Investment Costs:
High.

Maintenance Costs (yearly):
Medium (10-50%).

02 Vernacular / Non-engineered dams

Environmental impact	2/3
Risk protection	2/3
Durability	1/3
Affordability	2/3

Intro

Next to engineered floodwalls (see Measure [01]), there are simpler dams, dikes, and levees made from local materials and without an impervious core. These can include piles of soil, earth, sand, wood, vegetation, stones, or rocks. Vernacular dams are a specific type of such nature-based dams. They describe structures that are created from locally available materials and make use of context-specific traditional knowledge and construction techniques.

Dikes and levees can also occur fully based on geological processes. For example, naturally occurring dikes describe a body of rock blocking water flow, often originating from volcanic action. Natural levees form due to accumulated sediments *(sand, gravels, silts, clay)* after repeated flooding. Combining vernacular and natural dams with engineered structures (including an impervious core) can be particularly efficient in terms of the environmental impact, risk protection, durability, and affordability of a dam, dike, or levee.

Benefits and Risk

Compared to engineered structures, vernacular dams, dikes, and levees benefit from their cost-effectiveness due to the local material use and simpler construction. In addition, they have a lower environmental impact than engineered dams because vernacular/natural dams usually seek to blend into the surrounding ecosystems and environmental context. Finally, vernacular structures are often based on local knowledge and community engagement.

However, vernacular dams, dikes, and levees are generally not as resistant to extreme weather events as engineered solutions and are more prone to erosion, overtopping, slope failure, and damage. That is also because they are commonly of smaller scale and do not involve the same safety features *(e.g., flood gates)* compared to engineered structures.

When constructing dikes, it should be considered that the constructions can lead to a more intense and faster river flow. Moreover, if dikes do not have a proper watertight core *(as the engineered ones have)* and are porous, the water may pass under the dike. Constructing vernacular dikes in regions with clay soils, wetlands, or marshes should also be avoided for the concern of environmental stressors and the risk of drying the areas up if they are not regularly flooded. Consequently, the vernacular dams themselves are often most effective in combination with engineered measures.

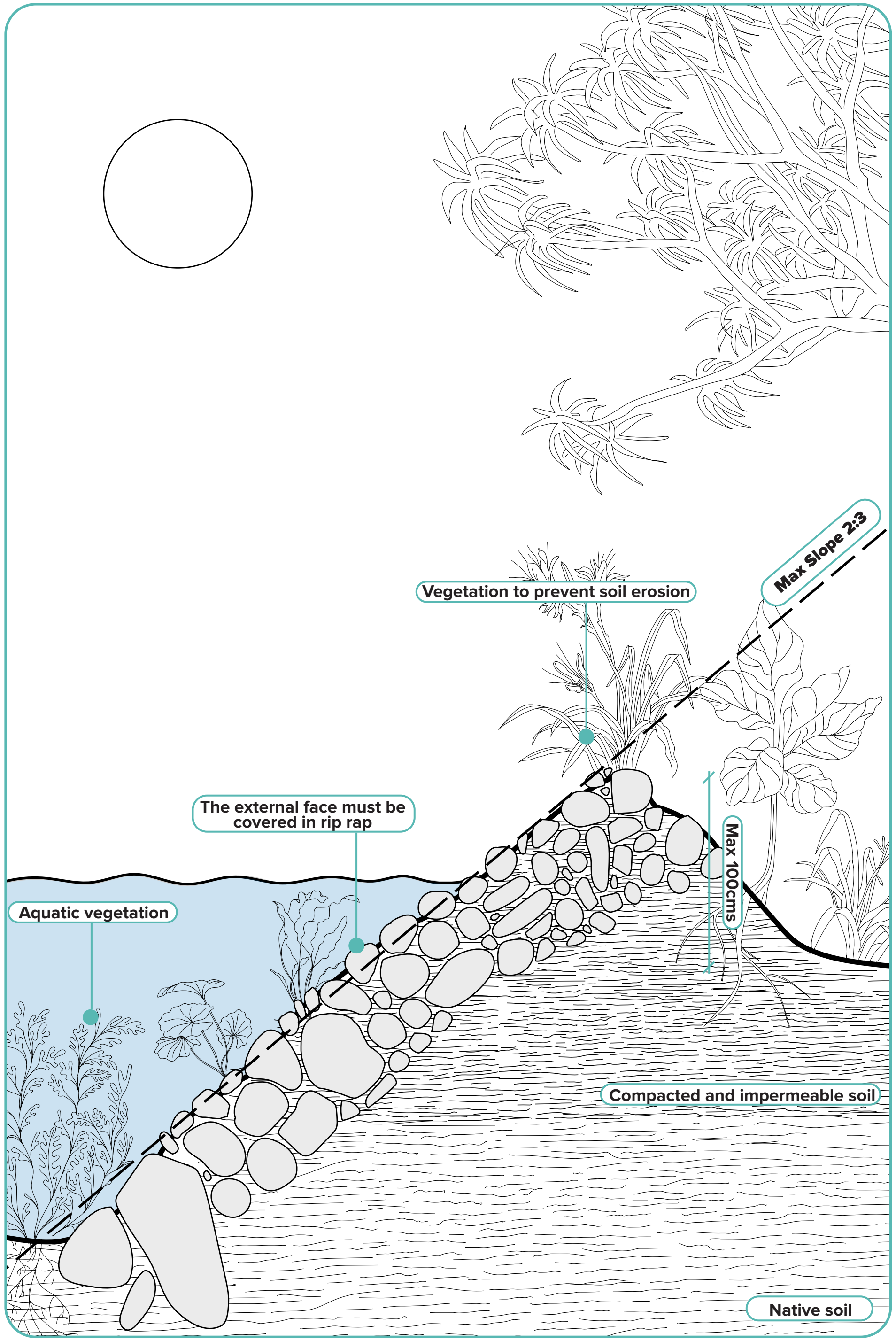


Fig. 04: *Example of an earthen dike in the Al-Redis Refugee Settlement. Philippe Reymond, UNHCR 2023.*

Good practice

Earthen dike in the Al-redis Refugee Camp, Sudan
To protect the residential areas in the Al-Redis refugee settlement in Sudan, an earthen dyke alongside the settlement was constructed during an emergency in 2022. Although the dike has a protective impact on the shelters, it cannot ensure appropriate access during long time periods of the year. That is due to the inundation of the access road to the settlement which could not be averted by the dike.

ACE Geosynthetics (2020)
Riverbank and Channel Protection. Levees and Dikes. Available online at https://www.geoace.com/app/Riverbank-and-Channel-Protection/Levees-and-Dikes.

Martinez, Maria; Bakheet, Ramez; Akib, Shatirah (2021)
Innovative Techniques in the Context of Actions for Flood Risk Management: A Review. In Eng 2 (1), pp. 1–11. DOI: 10.3390/eng2010001.

Tariq, Muhammad Atiq Ur Rehman; Farooq, Rashid; van de Giesen, Nick (2020)
A Critical Review of Flood Risk Management and the Selection of Suitable Measures. In Applied Sciences 10 (23). DOI: 10.3390/app10238752.

Overview of Criteria

Type of Intervention:
Hybrid.

Scale of Intervention:
Settlement, Supra-settlement.

Materials:
Soil, Sand, Wood, Vegetation, Stones, Rocks; Coir (Husk of coconut shell)

Environmental Impact:
Due to their natural occurrence or the use of locally available materials, the environmental impact is comparatively low, and vernacular solutions tend to blend into the surrounding ecosystems. However, dikes and levees can lead to a more intense and faster river flow, erosion, or slope failure. In regions with clay soils, wetlands, or marshes, their construction could trigger environmental stressors and the drying up of the surrounding areas.

Targeted Natural Hazard:
Coastal / Riverine Flood.

Targeted Vulnerable Assets:
Buildings, Land Cover.

Strategy Type:
Reduce Hazard Magnitude.

Implementation Time:
Short (1 day – 1 month), Medium (1 month – 1 year).

Effect Duration:
Medium-term (1 year to 10 years), Long-term (>10 years).

Investment Costs:
Low (Vernacular Dams).

Maintenance Costs (yearly):
Low (<10% investment costs).

03 Geotextile tubes and containers

Environmental impact	3/3
Risk protection	2/3
Durability	2/3
Affordability	3/3

Intro

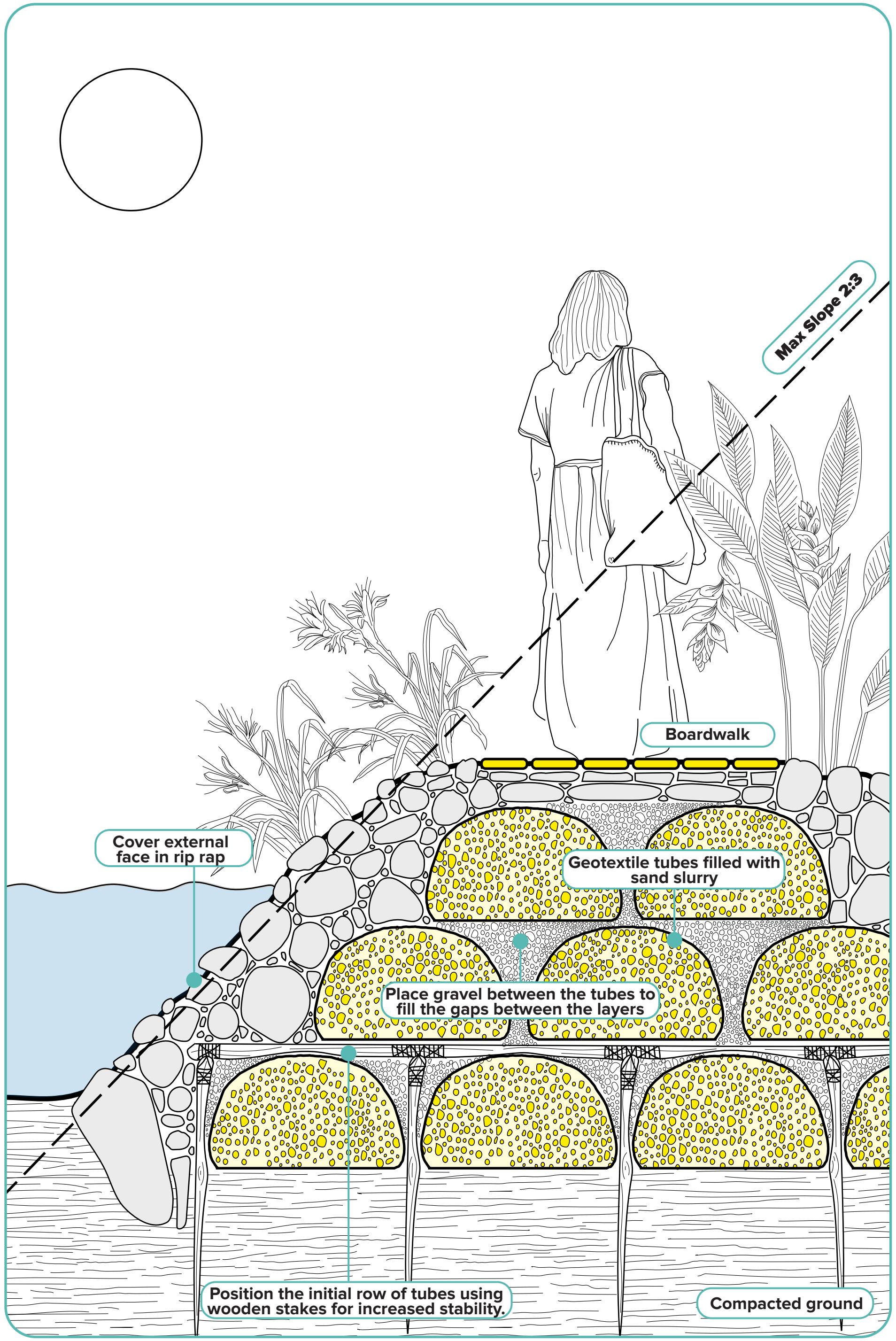
Geotextile tubes and containers can function as a special form of dike or support other structures like seawalls, dunes, and breakwaters. The flexible containers are filled with solids from the local site. The local filling materials usually comprise of a sand and water slurry that is then filled into the container by a pump, dredger, or funnel. Once the geotextiles are filled with the slurry, the water dissipates through the flexible and synthetic fabrics. The sand then prevails as the tube's main composition.

Benefits and Risk

Geotextile bags and tubes protect dunes, coasts, and riverbanks from erosion and flooding. In addition, they act as water filters or dewatering systems. The fabrics are highly permeable, tensile, durable, and can resist "abrasion, ultraviolet light, oxidation, acid, alkali, bio-decomposition and immersion corrosion in seawater" *(ACE Geosynthetics 2020).* The use of local sources *(including less transportation and costs)* makes the concept of geotextile containers an eco-friendly, easy-to-apply and cost-effective alternative to, e.g., flood protection with concrete.

Good practice

Geotextile containers in Ada Foah, Ghana
The application of geotextile tubes and containers took place in the town Ada Foah on the southeast coast of Ghana. The shoreline of Ada Foah is prone to serious erosion, reaching up to 50 meters of beach loss and resulting in the damage of settlements. To install the geotextiles, the sand has been dredged from the adjacent Volta River, which also supports the mitigation of floods because it decreases the river roughness and lessens the risk of flooding. Applying the highly permeable geotextile containers has helped to mitigate erosion and extreme weather events, including floods. Moreover, the geotextiles foster the restoration of sand dunes *(ACE Geosynthetics 2020).*



ACE Geosynthetics (2020)
ACETube - Hydraulic structures. Geotextile Bags, Tubes and Containers. Available online at https://www.geoace.com/products/Geotextile-Bags%2C-Tubes-and-Containers/ACETube%C2%AE-_-hydraulic-structures.

ACE Geosynthetics (2020)
ACETube Geotextile Tube Installation for Coastal Protection (Video). Available online at https://www.youtube.com/watch?v=s8yAtw4I-Ws.

ACE Geosynthetics (2020)
Shoreline Protection, Ada Foah, Ghana. Available online at https://www.geoace.com/case/Marine-and-Coastal-Structures-Construction/Shoreline-Protection%2C-Ada-Foah%2C-Ghana.

Overview of Criteria

Type of intervention:
Hybrid.

Scale of Intervention:
Shelter-Plot-Block, Settlement, Supra-settlement.

Materials:
Sand, Water, Geotextiles;
For implementation: Pump, dredger, funnel.

Environmental Impact:
The measure has an insignificant environmental impact due to local fill materials and no/limited transportation for the import of materials. CO_2 Emissions (kg/T): 2.4

Targeted Natural Hazard:
Pluvial Flood, Coastal / Riverine Flood.

Targeted Vulnerable Assets:
Buildings, Land Cover.

Strategy Type:
Reduce Hazard Magnitude.

Implementation Time:
Short (1 day - 1 month).

Effect Duration:
Medium-term (1 year to 10 years), Long-term (>10 years).
A geotextile tube lasts for around 5 - 15 years. Longer durability is possible.

Investment Costs:
Low, Medium
The costs are low compared to other fixed flood protection systems such as dams or revetments. Example (U.S. Context):$600 to $750 per meter of geotextile tube..

Maintenance Costs (yearly):
Low (<10% investment costs).

04 Bank protection (Riprap)

Environmental impact	2/3
Risk protection	3/3
Durability	3/3
Affordability	2/3

Intro

The protection of riverbanks and coasts aims to decrease the overall water velocity and to reduce (soil) erosion. It stabilizes the slopes through a cover of unconstrained and angular rocks or stones along channels, rivers, or waterbodies, often called “riprap”. Riprap can also be installed at slopes exposed to weathering and where it is not possible to plant vegetation. They can be built with natural material *(e.g., stones)* or artificial *(e.g., concrete blocks),* and can be either graded or uniform. The first includes stones of mixed size, while uniform riprap uses only one stone size. Graded riprap is usually preferred to uniform stones because it is easier and less costly to install. Bank protections can also be achieved with other construction methods such as gabion walls *(see Measure 05).*

Benefits and Risk

The benefits of riprap include its simple installation and maintenance. While well designed riprap allows shrubs to grow, larger vegetation such as trees should be removed because they may cause the riprap to collapse. Generally, if the riprap is not placed properly or along too steep slopes, there is a risk of stone movement. Moreover, riprap comes with the risk of creating scour in the lower parts of the installation. Compared to using vegetation for erosion reduction, riprap is more expensive and provides fewer habitats for other species. However, snakes tend to use the riprap as a habitat which needs to be communicated to the residents of the refugee settlements.

Good practice

Vegetated riprap.
Vegetated riprap incorporates a combination of rock and native vegetation in the form of live cuttings. It provides shade, cover, and input of small organic debris to the stream. At the same time, it improves the fish habitat and supports bank protection through root mass development. An additional benefit of vegetated riprap is a potential fodder supply for local animal populations. Note that well-graded riprap will form a dense and flexible cover that can adapt well, even on uneven surfaces, better than uniform riprap. Even if riprap is ranked as engineered works, when vegetated, it may become similar to the natural banks. Rriparian vegetation fosters the slowing down of the flow. Overall, the risk mitigation of vegetated riprap has a positive effect. However, in some specific cases, you may want to accelerate the flow (which induces a lowering of the flow depth).

Artificial riprap for flash flood mitigation.
When the soil and the embankment are loose, one could consider using artificial concrete elements for "armoring" the riverbed. These elements form a flexible layer, mimicking a large boulder. Their shape allows them to interlock and avoid large erosion.

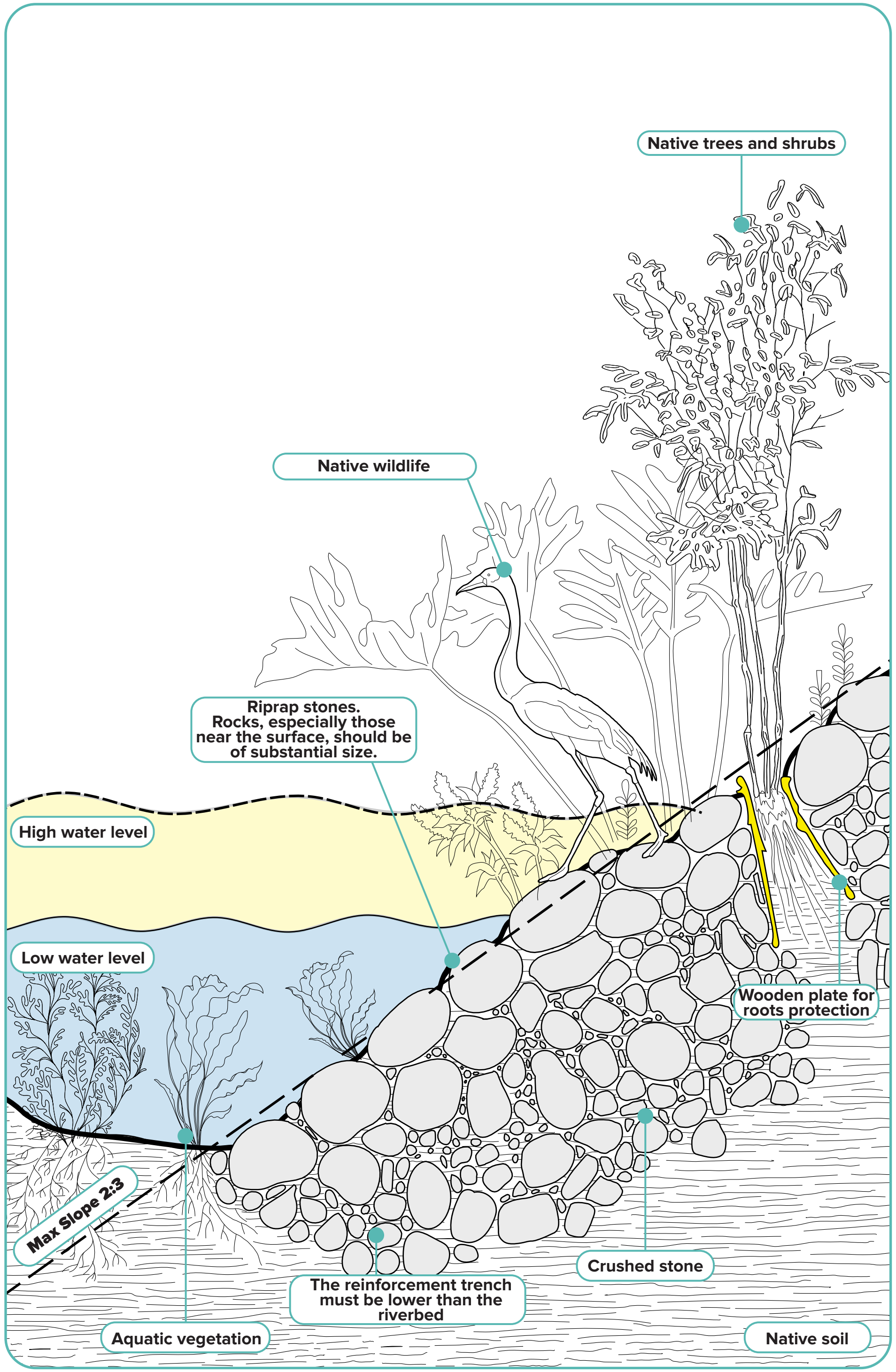


Fig. 05: *Well-designed riprap can help shrub vegetation to grow (Big trees can cause riprap to collapse and must be removed). Eric Bardou, UNHCR 2022.*

Fig. 06: *Example in a small creek in Switzerland. Eric Bardou, UNHCR 2022.*

Dale's Marine Construction Inc. (2021)
How to install riprap and have a good defining line between yard and riprap. Available online at: https://www.youtube.com/watch?v=627XcUiLfl0

Massachusetts Clean Water Toolkit (2023:04:51)
Riprap. Available online at https://megamanual.geosyntec.com/npsmanual/riprap.aspx, updated on 9/29/2023:04:51.

Flexamat (2022)
Negative Impacts of Riprap on Lakeshores. Available online at: https://www.flexamat.com/post/negative-impacts-of-riprap-on-lakeshores

Overview of Criteria

Type of intervention:
Engineered, Hybrid.

Scale of Intervention:
Settlement, Supra-settlement.

Materials:
Unconstrained/angular rocks, filter material (e.g., sand, gravel, crushed stone or filter fabric), sometimes concrete for artificial ripraps.

Environmental Impact:
Although riprap uses non-engineered materials (rocks), it is not considered as environmentally friendly because it requires high transport emissions for placing the rocks at the chosen location. Riprap also traps heat between the rocks which may affect the water temperature of the adjacent waterbody. The increasing water temperature can result in thermal pollution and changing aquatic ecosystems. Chemicals to avoid weed on the riprap can also harm the environment.

Targeted Natural Hazard:
Coastal/Riverine Flood

Targeted Vulnerable Assets:
Buildings, Transport, Land Cover.

Strategy Type:
Reduce Hazard Magnitude.

Implementation Time:
Short (1 day - 1 month).

Effect Duration:
Long-term (>10 years).

Investment Costs:
Medium

Maintenance Costs (yearly):
Low (<10% investment costs).
Annual check-ups, or after major weather events, concerning damages, obstructions, or woody vegetation (which needs to be removed) are necessary in terms of riprap maintenance.

05 Retention walls

Environmental impact	2/3
Risk protection	3/3
Durability	2/3
Affordability	2/3

Intro

While bank protection (riprap) reduces erosion along the embankments, sometimes retention walls are necessary to avoid landslides from the terrain above the water body. These can be built from different materials, including wooden or metallic planks, as well as gabion walls. Gabion walls describe galvanized mesh-boxes filled with rocks that are stacked in the form of closed cages. The purpose of the permeable gabion walls is to stabilize soils. Besides embankment stabilization, the also contribute to protect from flooding and to reduce the waterflow.

Benefits and Risk

The benefits of gabion walls include the use of local excavation materials which decreases the transportation costs and emissions. In addition, the intervention becomes more efficient in time due to vegetation that grows between the rocks and strengthens the structure. Due to their permeability, gabion retention walls hinder the water to build up behind the floodwalls and protects from waterlogging. Finally, the effect duration of gabion walls is comparatively long due to the stone blocks' durability.

Good practice

Gabion retention walls in the Swat Valley, Pakistan
In 2022, devastating floods took place in Pakistan. Among the affected areas was the remote Swat Valley in Khyber Pakhtounkhwa in the north-west mountainous region bordering Afghanistan. The strong rains caused rivers to quickly overflow, creating destructive flash floods along the main Swat Valley and its side valleys. In addition, numerous landslides caused massive destruction in the region. Many houses and public buildings were washed away, roads cut and bridges destroyed, leaving the villages without access to any external support.

The rapid emergency repair works included the reinforcement of infrastructures like roads and the installation of protection walls around buildings. For the latter, mainly gabion walls were used, since the adequate material is widely available in the region and the method is low-cost and quick to implement. The stones carried by the overflowing rivers could directly be crushed and used for gabion reinforcement walls, limiting the needs for transport to wire mesh only. This was especially well adapted for remote areas without car or truck access.

Right after the floods, the Swiss Humanitarian Aid sent a team to support emergency repairs to infrastructures and public buildings. Gabion was used for the emergency repairs of schools and to build reinforcement walls around the school grounds, avoiding landslides and thus increasing the safety for the children. Four weeks after the disaster, the access to the first schools was possible, and at the end of the project after 3 months, 11 schools were rehabilitated through the action, allowing more than 1'400 children to go back to school.

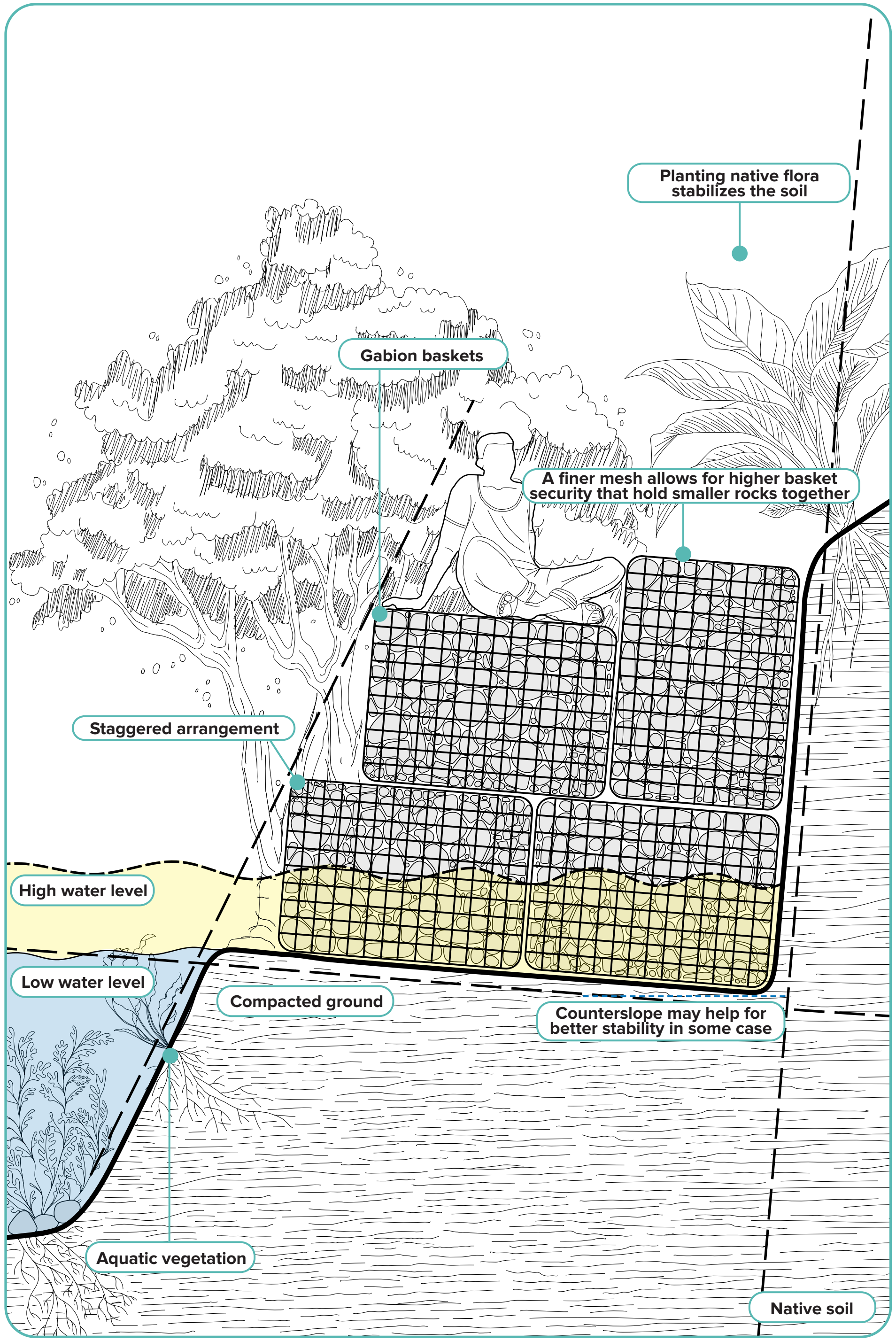


Fig. 07: *Torwal school in the Swat Valley, Pakistan. Rehabilitation works with gabion walls. Christian Neuhaus, SDC 2022.*

IOM Yemen (2022)
Gabion Walls Protect Displaced People's Life from Floods in Taiz. Available online at: https://www.youtube.com/watch?v=x5psinEYZWg

Fine Mesh Metals (2021)
Gabion Standard Design. Available online at [https://www.gabionbaskets.co.uk/gabion/gabion-wall-standard-design.](https://www.gabionbaskets.co.uk/gabion/gabion-wall-standard-design)

Geotech (2023)
Gabion walls – function, application, advantage. Available online at [https://www.geotech.hr/en/gabion-walls/.](https://www.geotech.hr/en/gabion-walls/)

Overview of Criteria

Type of Intervention:
Engineered, Hybrid.

Scale of Intervention:
Settlement, Supra-settlement

Materials:
Galvanized meshes, stone rocks.

Environmental Impact:
Gabion retention walls show low transportation emissions due to local material use (if locally available).

Targeted Natural Hazard:
Coastal/Riverine Flood

Targeted Vulnerable Assets:
Buildings, Land Cover.

Strategy Type:
Reduce Hazard Magnitude.

Implementation Time:
Short (1 day - 1 month).

Effect Duration:
Long-term (>10 years).

Investment Costs:
Low

Maintenance Costs (yearly):
Low (<10% investment costs).

06 | Seawalls and Groynes

Environmental impact	1/3
Risk protection	2/3
Durability	3/3
Affordability	1/3

Intro

Seawalls are large and engineered installations to protect the coast and shoreline from the impact of the sea. Most commonly, they are constructed as vertical armors along the coast. However, seawalls can also be built perpendicularly from the shore (in some contexts called “groynes”, for managing the sediment budget of beaches) or can be freestanding in the sea with a distance from the shore (also called “breakwaters”). The structures can be combined with tetrapods and geotextile containers, among others. Due to their reverse risks, scale and costs, seawalls should not be prioritized in the context of refugee settlements.

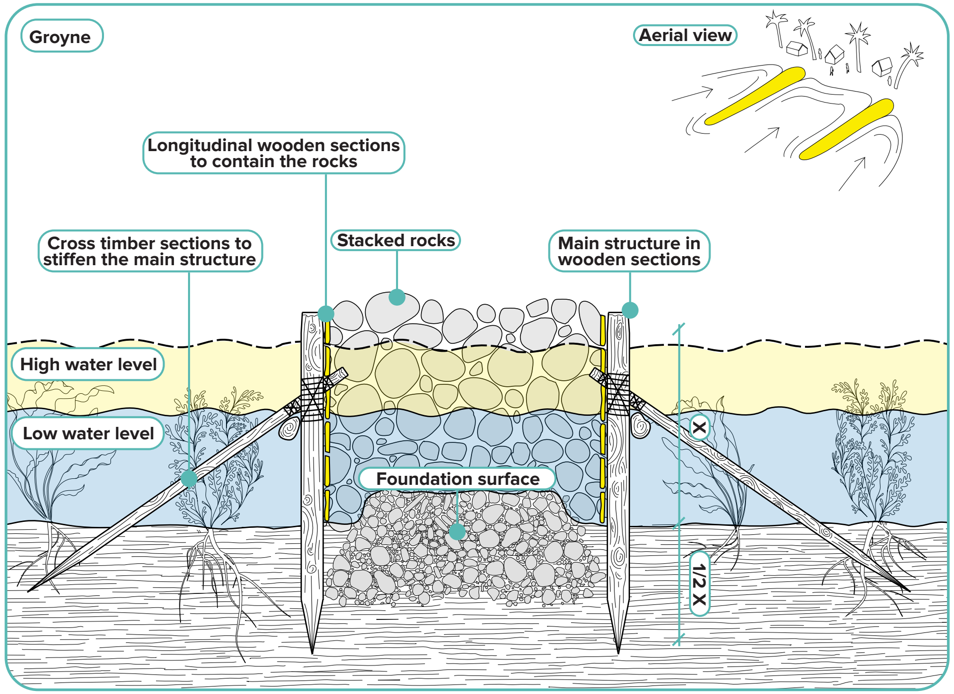
Benefits and Risk

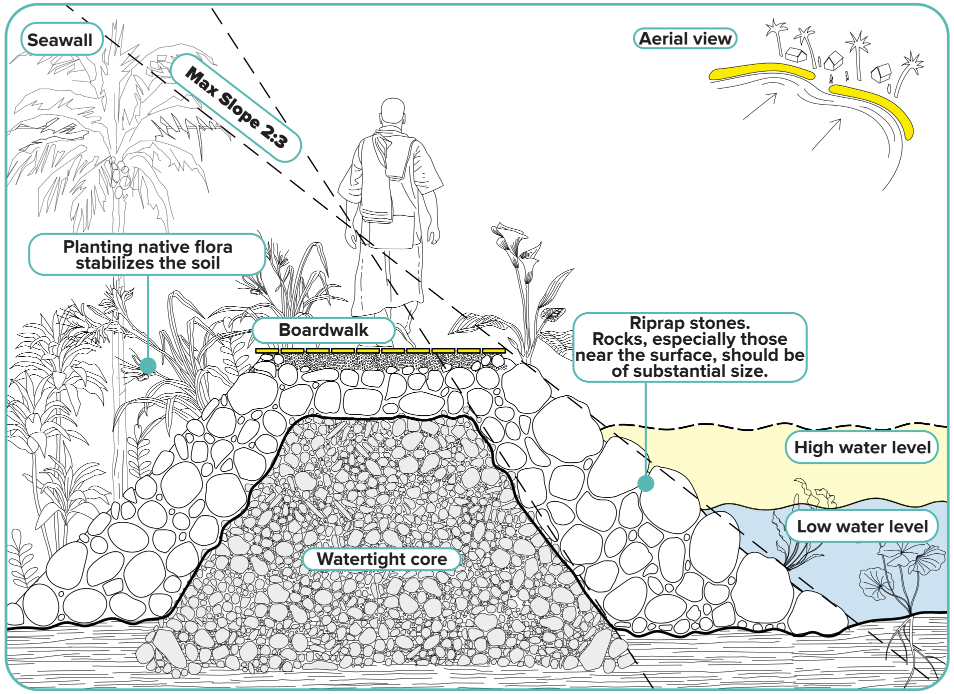
Seawalls can benefit the shoreline protection and the uplands by mitigating the damaging effects of waves, tides or storm surges. However, the vertical design of seawalls results in the sharp reflection of the waves, which accumulate the energy at the bottom or toe of the structure which can lead to its deterioration over time.

In general, the large coastal structures can cause extensive harm to the beaches as well as to the marine and coastal environment. In this light, larger coastal structures should be built only in combination with comprehensive environmental assessments and management.

Good practice

TetraPOT concrete blocks with mangroves.
The TetraPOT is a hybrid form of sea defense as it combines concrete blocks (also: tetrapod) and large pre-seeded and compostable plant pots for mangroves. Together with the mangrove root system, the blocks support flood defense, impede soil erosion, and protect natural habitats. The one-ton heavy tetrapod requires less concrete and production time than traditional sea defense bollards. In addition, the growing mangroves (protected from the concrete) can spread through holes in the engineered block. After around 14 months, the mangroves are grown enough to anchor the tetrapods through their roots (Tucker 2016).





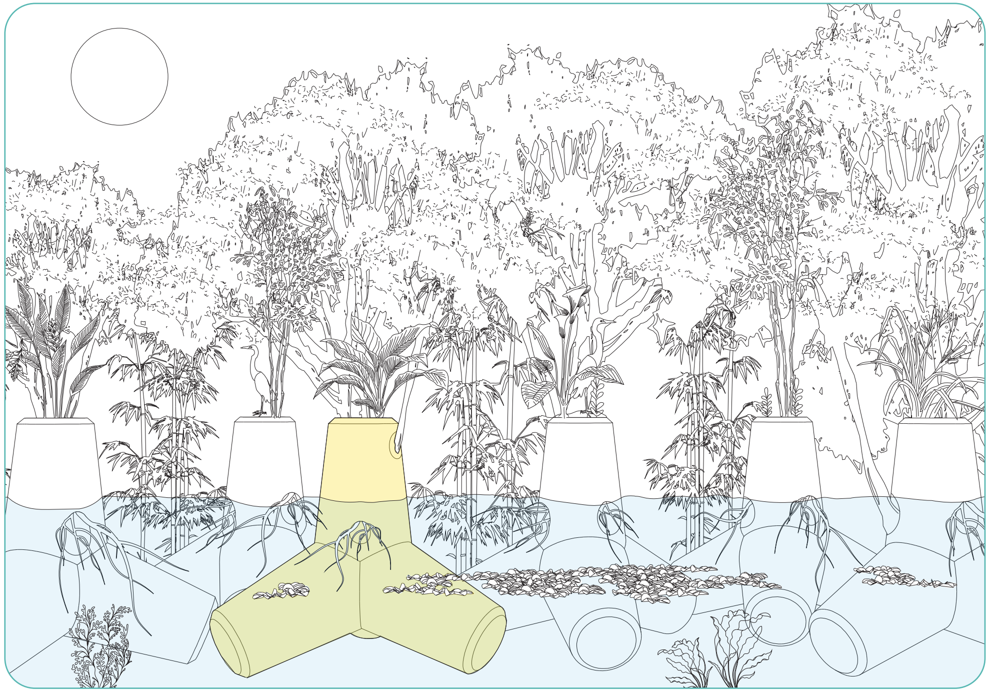


Fig. 08: *Example of a TetraPOT. Beaumé and Pabón 2023 based on Tucker 2016.*

Overview of Criteria

Type of Intervention:
Engineered.

Scale of Intervention:
Supra-settlement.

Materials:
Concrete, Metal, Timber, Steel (Selection).

Environmental Impact:
Seawalls can harm the marine and coastal environment and biodiversity. In addition, they can cause interruptions in habitat migration.

Targeted Natural Hazard:
Coastal/Riverine Flood

Targeted Vulnerable Assets:
Buildings, Transport, Technical Infrastructure, Land Cover.

Strategy Type:
Reduce Hazard Magnitude.

Implementation Time:
Medium (1 month - 1 year).

Effect Duration:
Long-term (>10 years).

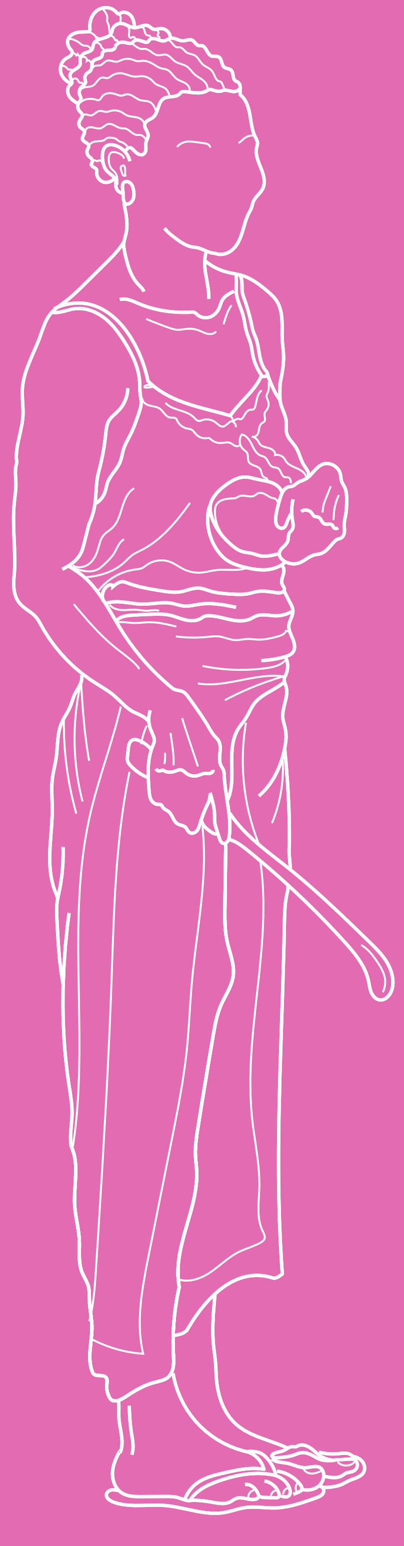
Investment Costs:
High.

Maintenance Costs (yearly):
Low (<10% investment costs).

Climate ADAPT (2023)
Seawalls and jetties.
Available online at
https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/seawalls-and-jetties, updated on 9/29/2023:17:14.

Tucker, Emma (2016)
TetraPOT is a greener alternative to concrete coastal defences. In dezeen.
Available online at
https://www.dezeen.com/2016/10/24/tetrapot-coastal-defence-design-plant-pot-sheng-hung-lee-china/.

Watson, Donald; Adams, Michele (2010)
Design for Flooding: Architecture, Landscape, and Urban Design for Resilience to Climate Change: John Wiley & Sons Inc.
Available online at
https://www.wiley.com/en-us/Design+for+Flooding%3A+Architecture%2C+Landscape%2C+and+Urban+Design+for+Resilience+to+Climate+Change-p-9780470475645#download-product-flyer.



II. Surface water management

Introduction and summary: Surface water management

Surface water management and drainage systems are critical in refugee camps. They support flood risk mitigation through adequate stormwater runoff and infiltration. They also ensure the overall (surface) water quality by rainwater filtration and its collection for further use. Surface water management should consider the entire area of the refugee camp as well as its surrounding landscape. Particularly drainage systems require a comprehensive understanding of the topography, its contour lines, and potential water quantities brought by rainfall, the runoff. Based on that the flow paths to the existing drains and drainage networks and the (sub-) catchment areas must be carefully studied. As a result, guiding principles for drainage systems in humanitarian settlements include:

• The drainage system needs to be planned as a whole from the source over all different steps down to the last discharge point.
• The further downstream the drainage system is installed, the more drainage capacity it requires.
• Upstream erosion should be avoided to ensure the downstream area remains free from silt and other blocking materials.
• Stagnant water should be avoided, especially in residential areas, and the separation of greywater from main drains should be supported.
• Drains require gentle and manageable slopes (approximately 2% is ideal).
• Check dams, steps, filtration, geotextiles, and upstream water storage will decelerate the downstream water flow, while brick and concrete drains tend to accelerate the flow.
• The height, materials, and size of drains depend on the expected water flow (based on the amount of rain and the rainfall-surface-runoff coefficient of the local ground) and the area's slope. For example, brick and concrete drains are the most effective in dense locations.
• The outlet of the drain must be carefully designed to avoid erosion and the spread of non desirable matters.

In the context of surface water management, the following chapter introduces four measures:

1. Drainage Systems (*see Measure [07]*)
2. Bioswales and Infiltration Basins (*see Measure [08]*)
3. Rainwater Harvesting and Retention Basins (*see Measure [09]*)
4. Permeable Ground and Pavement (*see Measure [10]*)

Please note that the combination of the here listed measures can help address the complete cycle of water management while considering the entire area of the refugee camp. Complementing the surface water management with nature-based solutions will augment the efficiency while participating in a sustainable cycle of water management. Especially measures like installing green roofs and walls together with water harvesting (*see Measure [15]*), or planting trees (*see Measure [17]*) to increase water infiltration will contribute to a better impact of combined measures.

07 | Drainage systems

Natural and low tech drains		High and medium tech drains	
Environmental impact	3/3	Environmental impact	2/3
Risk protection	2/3	Risk protection	3/3
Durability	2/3	Durability	3/3
Affordability	3/3	Affordability	2/3

Intro

Drainage systems require a global planning at the different scales of a settlement, and a comprehensive understanding of the surrounding areas and (existing) drainage networks (see introduction "Surface Water Management"). Drainage networks can take many forms and include several techniques and materials such as:

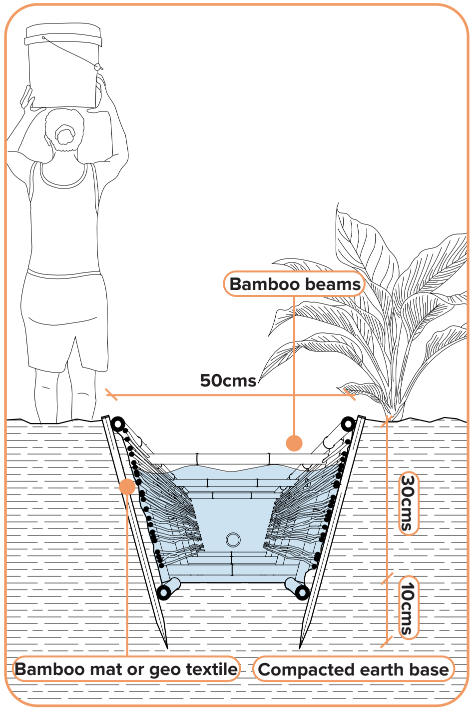
a. **Natural drains** (primary canals) are based on restorations of riparian vegetationand planting of trees and other shrubs. This nature-based measure comprises natural canals with low gradients where the water runs slowly.
b. **Low-tech drainage systems** can include interventions like bamboo drains (primary, secondary, tertiary drainage) and geotube/geobag embankment drains (primary, secondary, tertiary canals).
c. **Medium and high-tech drainage systems** describe measures such as masonry and precast concrete drains (secondary, tertiary canals). When using concrete ditches, re-infiltration through holes in the drainage bottom should be used wherever it is possible.
d. **Other interventions** include ridgeline and cascade drains, silt and waste traps, and microsoak pits.

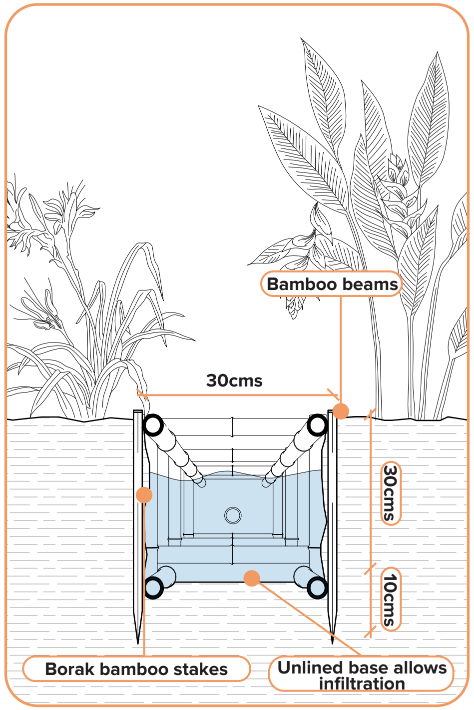
Good practice

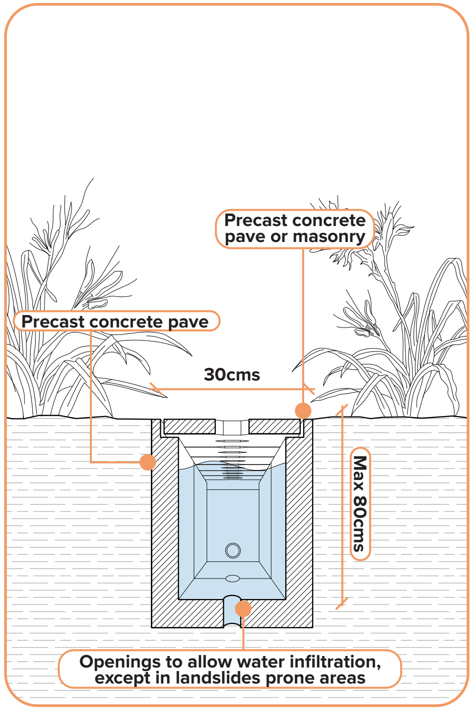
In general, if the drainage is not properly maintained and cleaned or the slope and infiltration effectively planned, there is a risk of stagnant water where mosquitos and will grow and transmit diseases.

a. **Natural drains:** Natural drainage is low in cost and eco-friendly. However, it is not recommendable in congested locations and there is the risk of erosion.
b. **Bamboo drains:** Bamboo drains are quickly installed and efficient during emergency situations, where this material is easily available. However, the bamboo does not last long and needs to be replaced frequently, so over time more durable solutions should be developed.
c. **Geotube/geobag embankment drains:** This low-tech measure is cost-and labor-effective. The base is made from well compacted earth which supports infiltration. However, the drains do not benefit highly dense areas.
d. **Masonry drains:** Masonry drains are beneficial for densely populated areas. In addition, their maintenance and cleaning are comparatively simple. However, the measure is costly and complex to install and repair. Also, the base (concrete/brick-based) may cause flooding downstream since there is no infiltration in the soil.

Precast concrete drains: The installation of precast concrete drains is best at road sides, ridge lines, or vehicular roads. Although they are installed relatively quickly, the material costs are high. Precast concrete drains are also at risk of accelerating the flow velocity and thus causing downstream flash floods. In general, very high-tech solutions are comparatively expensive and complex to build. That is the reason why they are seldom applied in refugee camp settings.







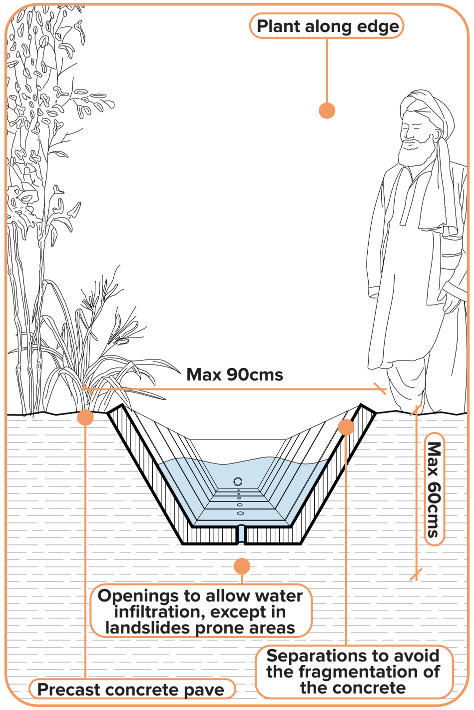


Fig. 09: *The SuDS management train under construction in the Gawilan Refugee Camp, Kurdistan Region of Iraq. Charlesworth et al. 2019, p.3505.*

IOM UN Migration (2020)
Site Improvement Catalogue.
Available online at
https://www.humanitarianlibrary.org/resource/iscg-site-improvement-catalogue.

susDrain (2022)
Sustainable Drainage.
Available online at
https://www.susdrain.org/delivering-suds/using-suds/background/sustainable-drainage.html

Charlesworth, Susanne M; Mctough, Mitchell; Adam-Bradford, A (2021)
The Design, Construction and Maintenance of a SuDS management Train to Address Surface water Flows by Engaging the Community: Gawilan Refugee Camp, Ninewah Governate, Kurdistan Region of Iraq.
Journal of Refugee Studies 34, 3494–3510.
Available online at
https://doi.org/10.1093/jrs/fez082

susDrain (2022)
SuDS management train.
Available online at
https://www.susdrain.org/delivering-suds/using-suds/suds-principles/management-train.html

Overview of Criteria

Type of Intervention:
Engineered, nature-based, hybrid

Scale of Intervention:
Settlement, Supra-settlement

Materials:
Bamboo drains: (Borak) bamboo, bamboo mats, basha bera mats, geotextiles, earth base (can be complemented with cement screed or trapaulin for better waterflow)
Geotube embankment: Geotube/bags, sand, Alternatively: Jutebags, seeds
Masonry Drain: Bricks, jute/geotextile bags filled with brick chips, concrete, beams
Concrete Drains: Concrete, compacted earth

Environmental Impact:
Bamboo drains include sustainable materials and support infiltration. Geotube embankments foster infiltration, but the earth base can increase siltation and erosion. Masonry and concrete drains may prevent waterlogging but can disrupt habitats through excavation and vegetation removal before the implementation.

Targeted Natural Hazard:
Pluvial Flood, Coastal/Riverine Flood

Targeted Vulnerable Assets:
Buildings, Transport, Technical Infrastructure, Land Cover

Strategy Type:
Reduce Hazard Magnitude, Reduce Asset Vulnerability.

Implementation Time:
Bamboo drains: short (1 day – 1 month)
Geotube embankments: Short (1 day – 1 month)
Masonry and Concrete Drains: Medium (1 month - 1 year)

Effect Duration:
Bamboo drains: short-term (< 1 year)
Geotube embankments: medium-term (1 year to 10 years)
Masonry and Concrete Drain: medium-term (1 year to 10 years), long-term (>10 years)

Investment Costs:
Bamboo drains: low
Geotube embankments: low, medium
Masonry and Concrete Drains: medium, high

Maintenance Costs (yearly):
Bamboo drains: Low (<10% investment costs)
Geotube embankments: Low (<10% investment costs)
Masonry and Concrete Drain: Low (<10% investment costs)

08 Bioswales and Infiltration basins

Environmental impact	3/3
Risk protection	
Rain gardens, bioswales	1/3
Infiltration basins	2/3
Durability	2/3
Affordability	3/3

Intro

Bioswales: *(also: Vegetated Swales)* describe low-lying, vegetated, or mulched channels with gentle slopes. As a nature-based alternative to engineered gutters or sewers, they can treat, reduce, decelerate, and absorb stormwater runoff. The intervention is particularly efficient in the event of less heavy but frequent precipitation. In larger stormwater events, bioswales still play a significant role in the overall runoff reduction and the removal of pollutants. However, a bioswale acts more like a corridor for the rainwater, leading it to another point *(e.g., into a rain garden or infiltration basins).* That is why bioswales are often used in combination with rain gardens and infiltration basins.

Rain gardens and infiltration basins: Rain gardens and infiltration basins mitigate the runoff during *(heavy)* rainfall by infiltrating the water flow. While both interventions have the same function and are characterized by highly permeable soils, rain gardens are smaller than infiltration basins. Rain gardens are mostly implemented at plot and community/block scale, the water being collected from the roofs close by or the water channeled through a bioswale. The infiltration basins tend to be of greater extent and mitigate direct stormwater runoff. As a result, rain gardens and infiltration basins serve as simple and sustainable measures to prevent the nearby shelter, public spaces, and pathways from being flooded. At the same time, they support groundwater recharge.

Benefits and Risk

Bioswales Besides channeling and infiltrating stormwater, bioswales offer various co-benefits. One such benefit includes the provision of new habitats for local flora and fauna. In addition, bioswales support the plants' uptake of nutrients and the removal of pollutants.

Rain gardens and infiltration basins: Next to supporting stormwater infiltration, rain gardens are easy to maintain and retrofit. They are nature-based, small-scale, and affordable. At the same time, rain gardens and infiltration basins can be a source of livelihood. They might generally improve the appearance of open spaces and remove the rainwater from pollutants before it enters the groundwater. However, rain gardens are mainly suitable for low flow capacities of rainwater.

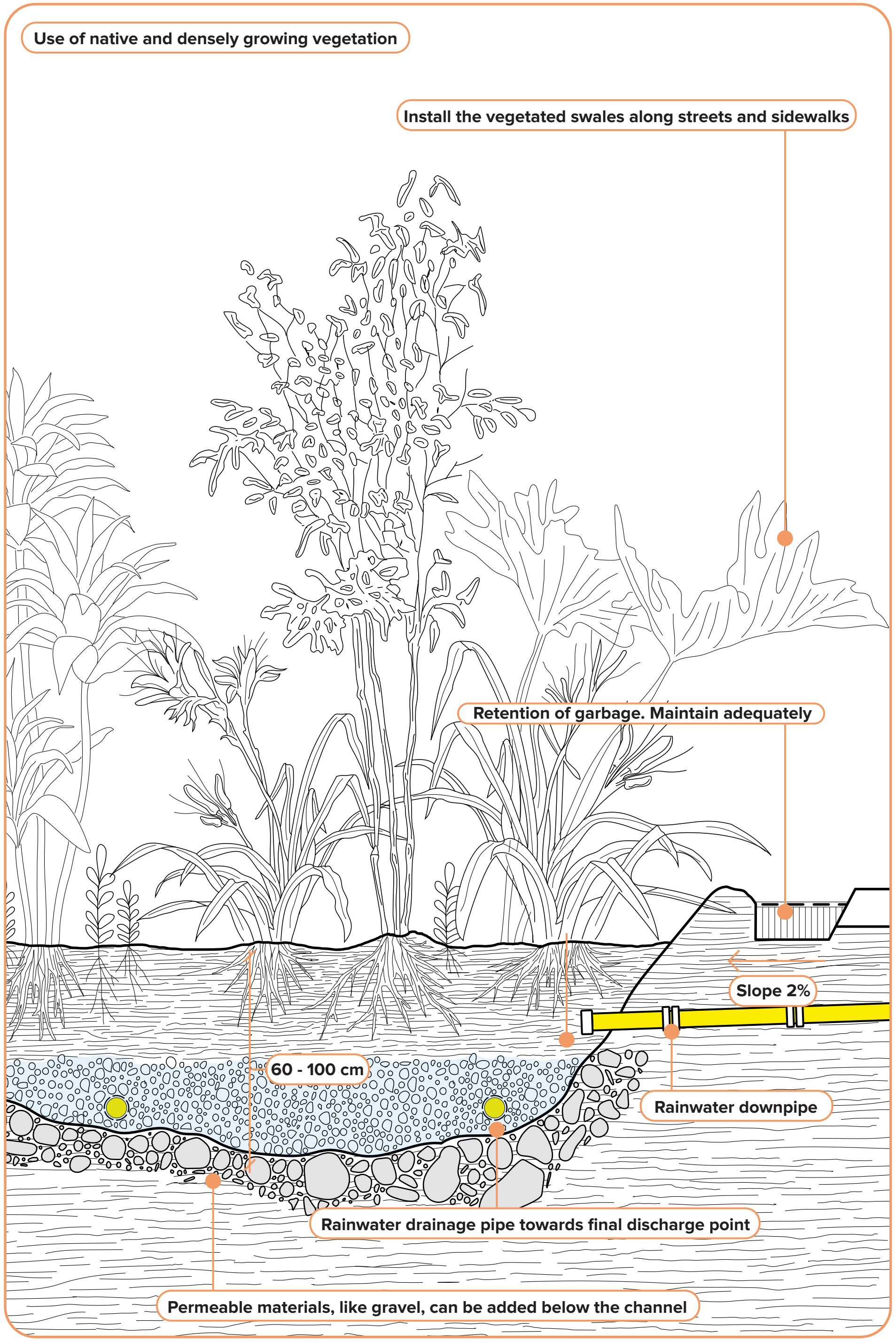


Fig. 10: *Community Garden in Bredjing refugee camp, eastern Chad. Nadia Carlevaro, UNHCR 2022.*

Good practice

Biofiltration stormwater management model Diepsloot informal settlement, Johannesburg.
To mitigate flood hazards in the informal settlement Diep Sloot in Johannesburg *(SA)*, a model for biofiltration stormwater management was developed. A co-benefit of the project was the creation of jobs and education in landscaping skills for the community. In this light, the model positively impacted the community's empowerment and stormwater management in the informal settlement *(Mseleku 2021)*.

Communal rain gardens in eastern Chad, Central Africa.
For about 20 years, the eastern region of Chad has been hosting many refugees in a rather arid climate. However, during rainy seasons, the low-lying areas near the wadis are often flooded. As a result, communal gardens have been developed. They serve as small buffer zones in the case of flooding while fostering productive use and community resilience. In this context, also the concept of permaculture can support the knowledge and identification with closed water cycles in agriculture. The organic and whole-circle idea of permaculture provides the community with reliable compost and self-grown crops.

Design Your Town (2022)
Example of Roadside planter. Available online at http://www.designyourtown.org/design_detail/planter-boxes/

Design Your Town (2022)
Vegetated Swales. Available online at http://www.designyourtown.org/design_detail/vegetated-swales/

Hu, Pengbo; Ma, Yue; Xue, Huifeng; Zhang, Feng (2019)
Application of low impact development technology in rainwater drainage system reconstruction project. In Cluster Computing 22 (1), pp. 533–543. DOI: 10.1007/s10586-017-1284-7.

Mseleku, E.S (2021)
Guidelines for Integrated Flood Control Design in the Informal Settlements of Cape Town Municipality. A case study of Kosovo, Philippi District.

Naturally Resilient Communities
USING NATURE TO ADDRESS FLOODING. Available online at http://nrcsolutions.org/.

Ruangpan, L.; Vojinovic, Z.; Di Sabatino, S.; Leo, L. S.; Capobianco, V.; Oen, A. M. P. et al. (2020)
Nature-based solutions for hydro-meteorological risk reduction: a state-of-the-art review of the research area. In Natural Hazards and Earth System Sciences 20 (1), pp. 243–270. DOI: 10.5194/nhess-20-243-2020.

Overview of Criteria

Type of Intervention:
Nature-based

Scale of Intervention:
Shelter/Block *(Bioswale, Rain Garden)*, Settlement *(Infiltration Basin)*

Materials:
Bioswales: Sand, Soil, Clay, Gravel, Native Vegetation.
Rain Gardens: Sand, Permeable Soil-Mix, Clay, Gravel, (Small) Native Vegetation, Wood (for Roadside Planters).
Infiltration Basins: Wood, Sand, Permeable Soil-Mix, Clay, Gravel, Riprap, Native Vegetation (incl. trees, bushes, smaller vegetation).

Environmental Impact:
Bioswales and rain gardens support the groundwater quality and provide new habitats for local flora and fauna. However, the soil and vegetation can become contaminated due to the use of fertilizers or highly polluted stormwater *(e.g., rubbish and clay)*. The concentration of pollutants may cause overall permeability reduction, leading to ponding water and diseases. Moreover, invasive species and mosquito breeding might negatively impact the environment due to waterlogging in rain gardens. Possible soil and ecosystem disturbances must be considered during the construction of rain gardens.

Targeted Natural Hazard:
Pluvial Flood.

Targeted Vulnerable Assets:
Buildings.

Strategy Type:
Reduce Hazard Magnitude.

Implementation Time:
Short (1 day - 1 month).

Effect Duration:
Bioswale, Rain Garden: Medium-term (1 year to 10 years).
Infiltration Basin: Long-term (>10 years).

Investment Costs:
Low:
The installation and maintenance costs are comparatively low in terms of time and finances, mainly if native plants are involved.

Maintenance Costs (yearly):
Low (<10% investment costs).

09 Rainwater harvesting and retention basins

Environmental impact 3/3
Risk protection 2/3
Durability 2/3
Affordability 3/3

Intro

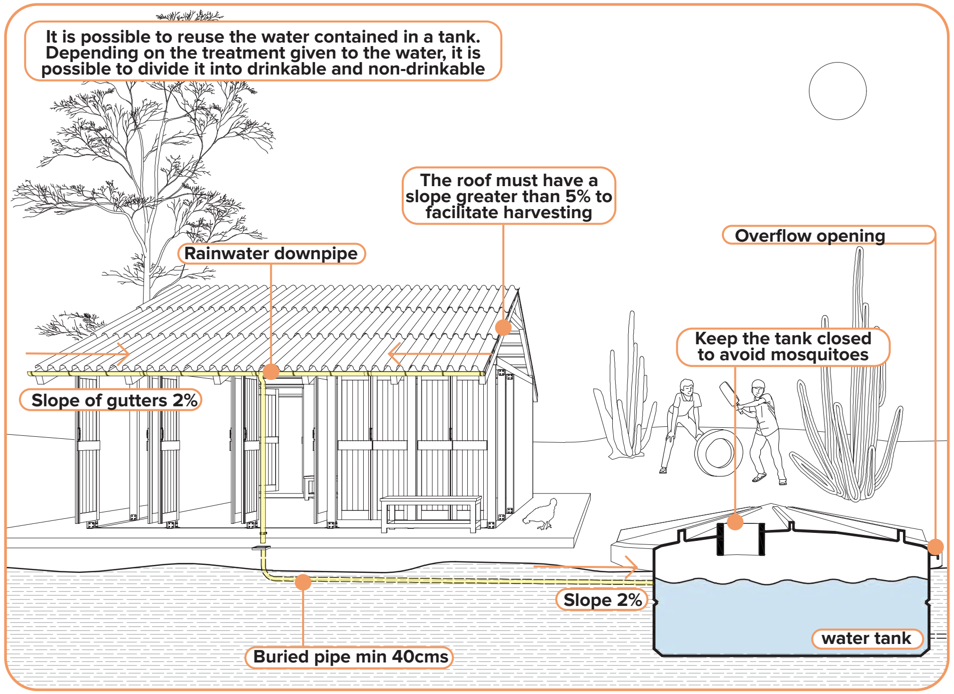
Rainwater harvesting (RWH) describes the process of collecting and storing rainwater. The practice enables the storage of stormwater runoff from rooftops, courtyards, greenhouses, reservoirs, retention ponds or other built infrastructure. This is also the first element of most drainage systems. Water can be directly channeled to drains in the ground or harvested for further use. There are several possibilities to harvest rainwater such as by using water tanks, rain barrels, and cisterns. Cisterns can be as simple as large containers located on rooftops for rainwater storage. Commonly, the harvested water comes into use for irrigation, firefighting, toilets, sinks, showers, or laundry making. RWH is particularly useful in the context of humanitarian settlements, in rural areas, bothin (semi-) arid or tropical climatic conditions.

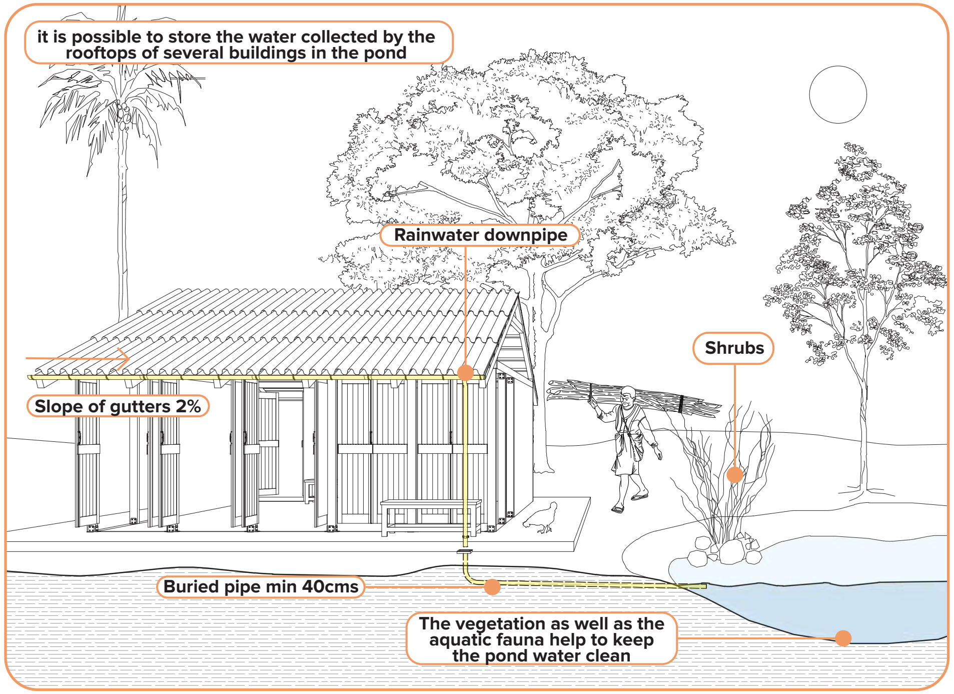
Retention basins *(also: wet ponds)* are a special type of rainwater harvesting and/or infiltration basins *(see Measure [08])*. They show a permanent water level which, during heavy rain events, can store further amounts of stormwater runoff while improving the water quality based on natural processes. Mostly, the collected water in wet ponds is used for irrigation or watering livestock.

Benefits and Risk

Next to stormwater flood mitigation, RWH provides benefits such as food security and the conservation of local water resources. The idea of circular design stresses water reuse (and thus the use of greywater) for landscape irrigation, topsoil treatment, or toilet flushes. By reusing greywater there is less strain on freshwater supplies, septic tanks, and the overall use of chemicals. In contrast, the reused water may support land fertility by making use of nutrients that would have been most likely wasted.

Depending on the treatment of the harvested water, possible usages may be different *(e.g., if chlorinated, it is useful for cleaning and sometimes can be even drinkable but is less adequate for irrigation).* If greywater is reused for irrigation, they first need to be filtrated to remove soap and other pollutants. When installing such systems, it is important to properly inform the users about the possible usages of the water, and the uses to avoid.





Good practice

Filtered RWH In Mexico City, Mexico.
In Mexico City, the non-profit organization Isla Urbana developed RWH systems for informal urban settlements. After examining the areas that are most prone to water scarcity and capable of rainwater catchment, the organization implemented around 20'000 systems for rainwater collection and treatment across the city. After harvesting the precipitation on the rooftops, the water is cleansed with chlorine for the use of bathing and cleaning. The solution not only reacts to the issue of water scarcity but reduces the waste of stormwater and its possible damages through flooding and sewage system overspill *(Mseleku 2021).*

Unfiltred / graywater RWH in Guirhora Kello, Burkina Faso.
The British NGO Water Aid works together with national and local governments to support marginalized communities with safe water and sanitation facilities. That is also the case in the village Guirhora Kello in Burkina Faso, where rainwater runoff from the roofs of public buildings has been collected in storage tanks based on the ground. In this case, the stored water is not filtered and, thus, used as greywater for services such as washing, toilets, or planting. *(Mseleku 2021).*

Mseleku, E.S (2021)
Guidelines for Integrated Flood Control Design in the Informal Settlements of Cape Town Municipality. A case study of Kosovo, Philippi District.

Tasawwar, Sumbal; Kassaye, Rahel Birhanu; Schaldach, Ruth (2018)
Traditional Ecological Knowledge (TEK): Rainwater Harvesting Methods – A Review. Available online at https://www.ruvival.de/wp-content/uploads/2018/07/Traditional_Ecological_Knowledge_Rainwater_Harvesting_Working_Paper.pdf.

GRAF Ireland Environmental Ltd (2023)
How Do I Install A Rainwater Harvesting System? Available online at https://www.graf.info/en-ie/knowledge-hub/blog/how-do-i-install-a-rainwater-harvesting-system.html.

Go Smart Bricks (2019)
Top 7 Types Of Rainwater Harvesting Systems You Should Be Knowing (Go Smart Bricks). Available online at https://gosmartbricks.com/top-7-types-of-rainwater-harvesting-systems-you-should-be-knowing/.

Overview of Criteria

Type of Intervention:
Engineered, Hybrid

Scale of Intervention:
Shelter/Block.

Materials:
Clay, Concrete, Filter Systems, Cistern container

Environmental Impact:
RWH can have a positive impact on the natural environment since it helps with the conservation of local water resources, especially in times of water scarcity. In addition, RWH minimizes the need for complex water infrastructures such as piping systems. As a result, the overall environmental strains due to dams or treatment plants are reduced. The areas where greywater comes into use, should be carefully considered to avoid negative environmental impacts.

Targeted Natural Hazard:
Pluvial Flood.

Targeted Vulnerable Assets:
Buildings.

Strategy Type:
Reduce Asset Vulnerability.

Implementation Time:
Short (1 day - 1 month).

Effect Duration:
Long-term (>10 years).
Water tanks usually last between 10 and 20 years.

Investment Costs:
Low, medium.

Maintenance Costs (yearly):
Low (<10% investment costs).

10 | Permeable ground and pavement

Environmental impact	3/3
Risk protection	1/3
Durability	2/3
Affordability	2/3

Intro

Using permeable material for the surface of roads, pathways or other open spaces diminishes the overflow by increasing the overall pervious surface, allowing water to infiltrate the ground to limit runoff. Multiple materials can be used such as compacted gravel and sand for roads, or pavement systems with holes or large, permeable joints between the pieces. Pavements can be produced with different materials and promote the use of locally available materials whenever possible.

Combined with geotextiles, the PPS increase their porous capacity and cut the charges for operating sewer systems. Geotextiles remove pollutants from the water before it enters the ground, making it an eco-friendly solution for the downstream surroundings. This leads to the co-benefit of groundwater recharge. Overall, PPS is most effective in the context of short but heavy rainfall.

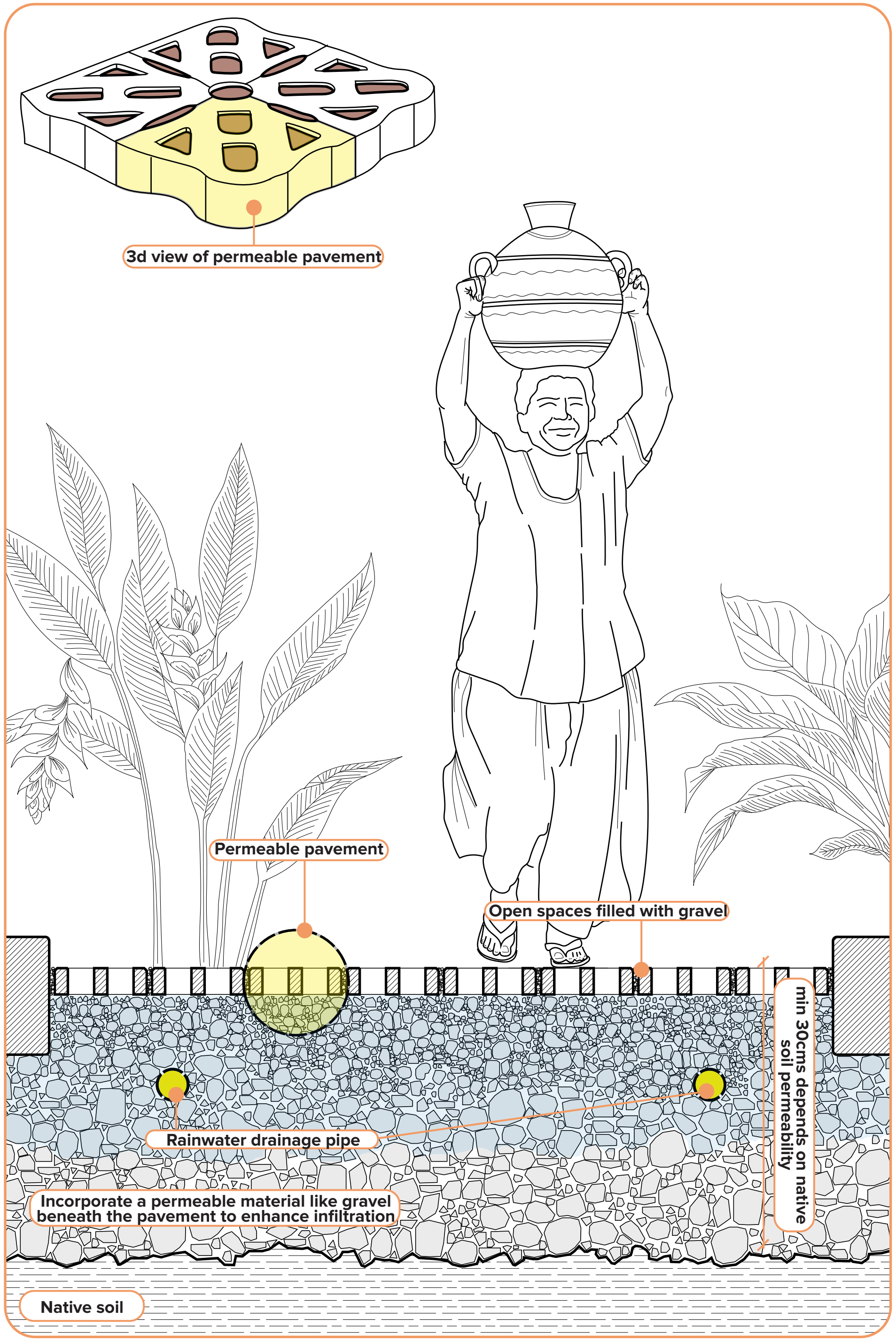
Benefits and Risk

The benefits include stormwater mitigation, which decelerates the deterioration of the overall infrastructure in refugee camps. However, permeable pavement tends to easily clog with debris or sediment and needs regular maintenance. The installation of PPS should, therefore, be avoided in areas with regular and high pollutant loads *(e.g., trash, sediment, chemical storage).*

In some cases, there can be a risk of increased runoff. That is when rainwater remains in the permeable pavement and mixes with the incoming stormwater. Finally, permeable pavement should be used mainly for pedestrians or low traffic due to its limited load-bearing capacity in the context of high and fast traffic.

Good practice:

Permeable terracrete blocks in the Langrug informal settlement, SA.
As a special type of Permeable pavement systems (PPS), 'terracrete' permeable pavements can be partly filled with soil and grass. Permeable terracrete blocks have been installed in the informal settlement of Langrug in Cape Town, South Africa. The goal of the pavement is to tackle the local concerns regarding stormwater flow, fouling of wastewater, littering, and solid waste. In Langrug, the installation paves 1000 square meters of road surface and is part of a wider water management system. It links to greywater disposal points and a pipe system that then leads into small wetlands and tree plantations instead of directly feeding into the municipal sewer system. The installation also includes the planting of indigenous trees along the pavements. The project (The Berg River Improvement Plan) was carried out by the Western Cape Government and Biomimicry SA *(Mseleku 2021).*



Overview of Criteria

Type of Intervention:
Hybrid.

Scale of Intervention:
Shelter-Plot-Block, Settlement.

Materials:
Concrete, Construction waste, Clay, Geotextiles (e.g. reeds, jute, coco), Soil, Grass.

Environmental Impact:

By filtering pollutants from the stormwater, permeable pavement (especially combined with geotextiles) can help improve the water quality of surrounding waterbodies and the groundwater. It supports the maintenance of the groundwater level, which benefits the local ecosystems, vegetation, and water resources. Nevertheless, some designs cannot filter every possible contamination. As a result, contaminants can easier reach the groundwater levels. Finally, terracrete permeable pavement helps reduce heat islands in settlements since the pavement can be combined with vegetation and allows the evaporation of water, which cools the pathways.

Targeted Natural Hazard:
Pluvial Flood.

Targeted Vulnerable Assets:
Buildings.

Strategy Type:
Reduce Asset Vulnerability.

Implementation Time:
Short (1 day – 1 month).

Effect Duration:
Long-term (> 10 year).

Investment Costs:
Medium
$120 – $170 per square meter (Context: Melbourne, Australia) (Concept Concrete 2022); 27 USD (530 ZAR) per square meter of terracrete grass block pavers (Context: South Africa) (Pavement Materials Group n.d.)

Maintenance Costs (yearly):
Low (<10% investment costs)
Due to the increased risk of clogging, regular maintenance is required (see 'Benefits' and'Risks'). Cleaning with a vacuum sweeper twice a year.

Concept Concrete (2022)
How Much Does Permeable Paving Cost? (Full Price Breakdown 2022) (Concept Concrete).
Available online at https://conceptconcrete.com.au/blog/how-much-does-permeable-paving-cost/.

Minnesota Stormwater Manual (2022)
Design criteria for permeable pavement.
Available online at https://stormwater.pca.state.mn.us/index.php/Design_criteria_for_permeable_pavement, updated on 9/29/2023:32:55.

Mseleku, E.S (2021)
Guidelines for Integrated Flood Control Design in the Informal Settlements of Cape Town Municipality. A case study of Kosovo, Philippi District.

Pavement Materials Group (2023)
Terracrete Grass Block Paver (350 x 350 x 100).
Available online at https://www.pavementmaterials.co.za/products/terracrete-grass-block-paver-suplier-south-africa, updated on 9/29/2023:28:05.

Sambito, Mariacrocetta; Severino, Alessandro; Freni, Gabriele; Neduzha, Larysa (2021)
A Systematic Review of the Hydrological, Environmental and Durability Performance of Permeable Pavement Systems. In Sustainability 13 (8), p. 4509. DOI: 10.3390/su13084509.

III. Adaptation of buildings and other assets

Introduction and overview: Adaptation of buildings and other assets

The general rule for mitigating the flood risk of shelters is to avoid building in areas that are prone to floods or landslides. As for choosing the location of refugee settlements and shelters: Low-lying riverbeds, fresh landfills, areas too close to rivers, the sea, or steep slopes should be refrained from. However, this is not always possible due to constraints in land availability, among other reasons.

Solutions to mitigate the damages of buildings and other assets situated in flood-prone areas can include:

a. Build on higher grounds (where possible)
b. Raise the ground of the building or of the area above the flood level
c. Allow the building to float
d. Strengthen the existing structures against flood events
e. Build protections to avoid water reaching the building

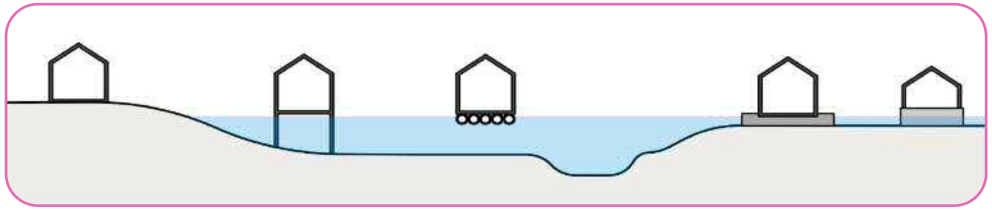


Fig. 16: *Build on higher grounds, elevated building, floating house, elevated building, consolidated structure. Patrizio Jellici 2023.*

The following chapter introduces five mitigation measures that support the adaptation of buildings in refugee camp areas that are prone to pluvial and riverine floods:

1. **Elevated Architecture** (*see Measure [11]*) (*see Measure [08]*)
2. **Amphibious Constructions** (*see Measure [12]*)
3. **Consolidated Structures** (*see Measure [13]*)
4. **Temporary Flood Barriers** (*see Measure [14]*)
5. **Green Roofs and Walls** (*see Measure [15]*)

Some of these measures can also be applied to other assets, such as roads and pathways, open areas, and agricultural lands. Concerning latrines, their superstructure can be considered as a building. However, the latrine pit or septic tank is most likely not eligible for applying similar mitigation measures. For this matter, materials to empty pits such as pumps would be more adequate and would need to be stored in preparedness of such events (*see measure [21]*).

11 Eleveted architecture

Environmental impact	3/3
Risk protection	3/3
Durability	2/3
Affordability	2/3

Intro

A common and comparatively simple practice against flooding is to elevate the foundation of assets (e.g., buildings, latrines, entire plots, cattle sheds). Originating from indigenous knowledge, raising the ground of structures takes place through piles, landfills, or stilts. When using stilts to elevate buildings, the structural soundness is primordial, especially in areas that are prone to heavy winds, landslides or earthquakes. Proper calculation of the structural design is necessary before building on stilts. A special type of elevated architecture are amphibious constructions *(see Measure [12])*.

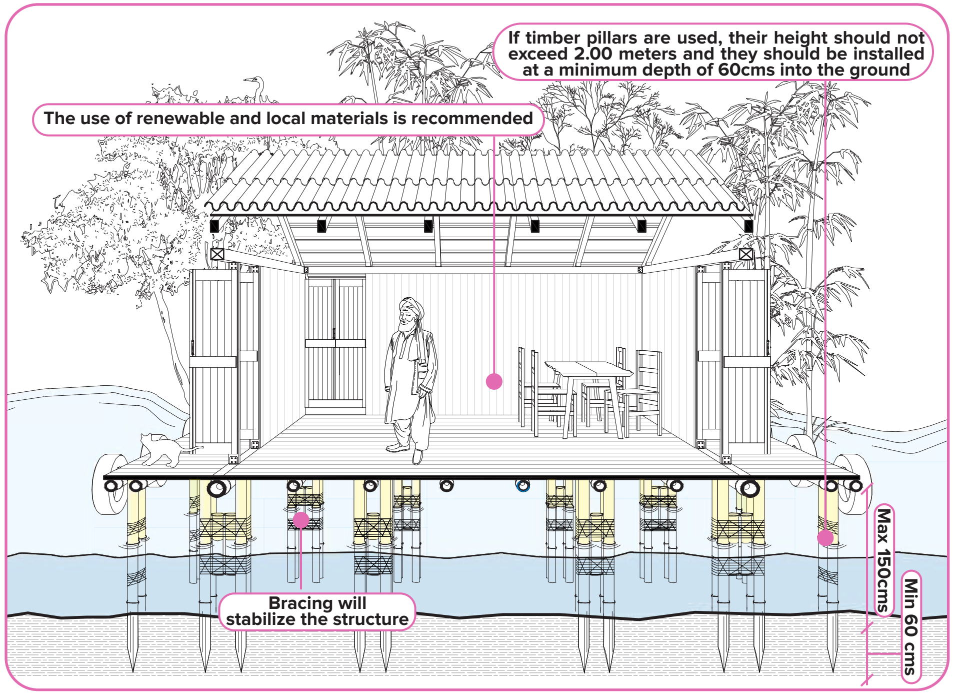
Benefits and Risk

The primary benefit of elevated architecture is the mitigation of flood impacts. In addition, raising the ground of structures can help overcome difficult terrain and site conditions, and propose additional room for storage underneath the shelter. On the other hand, elevated architecture can induce further risks by the failure of structural stability or difficult accessibility *(e.g., for people with physical impairments).* Moreover, while elevated assets can help preserve natural water flows and ecosystems, they can equally cause the risk of depleting nature on site, depending on the type of construction.

Good practice:

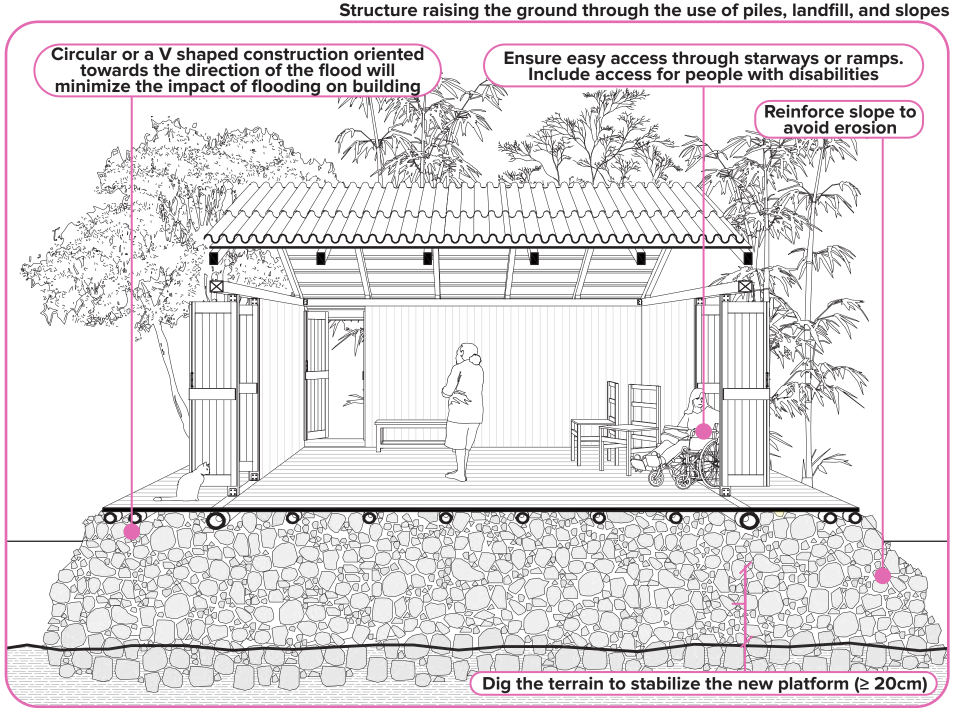
Elevation in the Mavrouni transit centre in Lesbos, Greece

Next to elevating single buildings, entire areas can be elevated. The Mavrouni transit center in Lesbos, Greece, is such an example. The center was built after the destruction of the Moria refugee camp due to fire. However, right after building up Mavrouni, one-third of the area was flooded. First, pallets were placed under the tents, which turned out insufficient to cope with the flooding. As a result, the entire area was elevated half a meter by a gravel layer. Such solutions are often very expensive, especially on a large scale, and need enormous quantities of material. Thus, they should be limited to smaller areas or avoided through an adaptation of the settlement planning.



Structure using stilts or columns

Structure raising the ground through the use of piles, landfill, and slopes



Overview of Criteria

Type of Intervention:
Hybrid.

Scale of Intervention:
Shelter-Plot-Block.

Materials:
(Selection) Wood, Sand, Soil, Clay, Timber, Bamboo, Thatch, Plastic cover.

Environmental Impact:
Environmental impacts can derive from the materials (extraction, production, transport) and energy needed for construction. In contrast to buildings on the ground, elevated constructions tend to increase the energy use for constructing structural supports, stairs, or landfills.

Targeted Natural Hazard:
Pluvial Flood, Coastal/Riverine Flood.

Targeted Vulnerable Assets:
Buildings, Technical Infrastructure.

Strategy Type:
Reduce Asset Vulnerability.

Implementation Time:
Short (1 day - 1 month), Medium (1 month - 1 year).
The implementation time comprises the site assessment, the excavation, landfill, leveling, and construction of the asset. The duration depends on the scale and complexity of the project. Unexpected issues, such as unfavorable weather conditions or logistics, can also prolong the implementation.

Effect Duration:
Medium - term (1 year to 10 years).
The effect duration of elevated structures depends on their design (e.g. built on stilts or landfills) and the local context. For example, the lifespan of landfills depends on their compaction, the quality and durability of the used materials, and how long they are able to withstand extreme weather conditions.

Investment Costs:
Medium.
Due to their more complex structure, elevated constructions can be more costly than constructions on the ground.

Maintenance Costs (yearly):
Medium (10-50%).

The Associated Programme on Flood Management (2017)
COMMUNITY-BASED FLOOD MANAGEMENT. Integrated flood management tools series. Available online at https://reliefweb.int/sites/reliefweb.int/files/resources/APFM_Tool_4_e.pdf.

UN-Habitat Myanmar (2015)
Manual on Flood - Causes, Effects & Preparedness. Available online at https://themimu.info/sites/themimu.info/files/documents/Guideline_Flood%20Manual_UN-Habitat.pdf.

12 | Amphibious constructions

Environmental impact	2/3
Risk protection	2/3
Durability	2/3
Affordability	2/3

Intro

Amphibious constructions are a valuable alternative to elevated buildings (see Measure [11]) which tend to be at risk of damage due to strong wind. Since temporary elevation to stay above water during flood events is the key concept of amphibious housing, theses constructions are less vulnerable to wind damage. In the case of flooding, the foundation of amphibious houses rests on the ground. The remaining parts of the house have a structural frame that floats depending on the intensity and depths of the flood event.

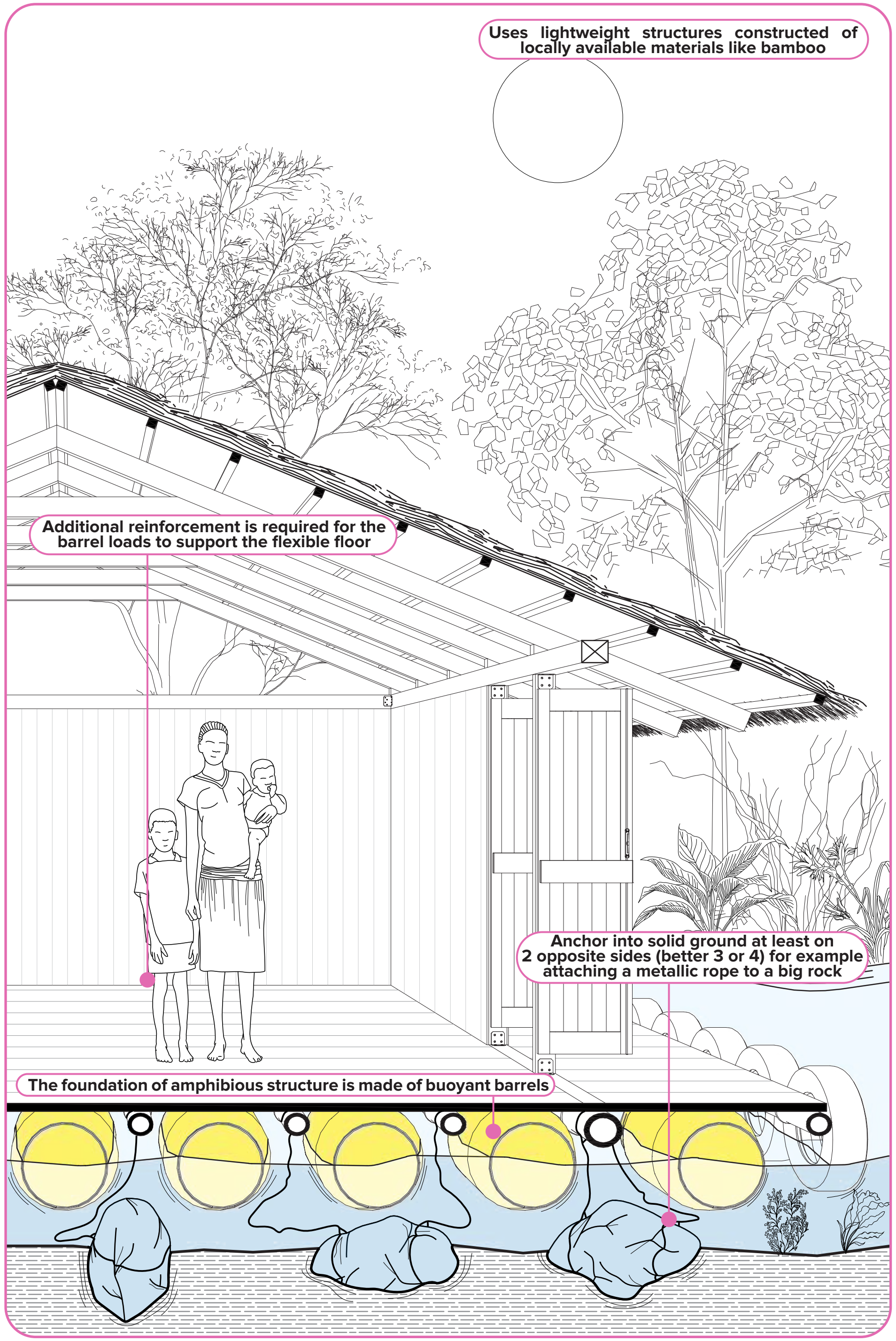
Benefits and Risk

In certain contexts, amphibious housing can be less expensive than permanently elevated housing *(see Measure [11])*. However, there is a need to investigate the impact of amphibious housing on water ecosystems since it may alter the water quality under and near the structure. The environmental impact depends on the scale and number of floating houses. Also, the design and interior of amphibious housing need a high level of accuracy to ensure the house does not face inclinations or the house's overall stability. Proper anchoring allowing the platform to rise with the water level while preventing it to derivate and crash against other buildings or objects is necessary.

Good practice

To tackle the flood risk in the most vulnerable settlements near Jamuna River in Sirajganj, Bangladesh, prototypes of floating houses were developed and implemented together with the community members. These prototypes retrofit existing housing structures by adapting the interior structure: The concept of buoyancy is used to design the floor as a hollow vessel, which ascends and sinks depending on the flood water level. The materials to construct the floor level comprise a lightweight surface that covers timber rafters. Both, the surface and rafters are made of timber. The void within the construction is then filled with reused plastic bottles.

The building process is undertaken in a participatory manner by involving the local communities, ensuring that the local people learn how to build the houses themselves. The involvement of the community contributes to local empowerment, creating identity and fostering the independent maintenance of the buildings. The project was carried out by the COmmunity REsilience through Rapid Prototyping of Flood Proofing (CORE) and the Bangladesh University of Engineering and Technology (BUET) *(Mseleku 2021)*.



Overview of Criteria

Type of Intervention:
Engineered.

Scale of Intervention:
Shelter-Plot-Block.

Materials:
Wood, Sand, Soil, Clay, Concrete, Timber, Steel, Barrels, Bamboo, Timber, Lightweight Surface, Timber Rafter (Wood), Plastic Bottles (see Good Practice)

Environmental Impact:
The carbon footprint of amphibious constructions depends on the refugee camp's location, the building's design, materials, maintenance, and transportation for the material delivery and construction. Generally, local (e.g., bamboo) and renewable materials can lower the carbon footprint. Minimizing material transportation and introducing solar and wind power benefits the overall environmental impact of amphibious constructions.

Targeted Natural Hazard:
Pluvial Flood, Coastal/Riverine Flood.

Targeted Vulnerable Assets:
Buildings.

Strategy Type:
Reduce Asset Vulnerability.

Implementation Time:
Medium (1 month - 1 year).

Effect Duration:
Medium-term (1 year to 10 years), Long-term (>10 years)
The lifespan depends on the construction materials, the refugee camps' exposure to natural hazards, maintenance, and repair.

Investment Costs:
Medium.
For example, a buoyancy system in Louisiana, US, costs around 5000 USD or less (English 2016).

Maintenance Costs (yearly):
Medium (10-50%)

Global Shelter Cluster (2018)
Shelter & Settlements.
The Foundation of Humanitarian Response. Geneva.

Leung, Tak (2014)
Amphibious Bamboo House.
Available online at
https://issuu.com/tak.leung/docs/amphibious_bamboo_house_issuu, updated on 9/29/2023:37:39.

Mseleku, E.S (2021)
Guidelines for Integrated Flood Control Design in the Informal Settlements of Cape Town Municipality. A case study of Kosovo, Philippi District.

Ullal, André; Estrella, Xavier (2021)
South Sudan - State-of-the-Art on Flood Resilient Shelters.
Available online at
https://infoscience.epfl.ch/record/292580

Anthes, Emily: Amphibious Architecture.
Float when it floods. In Anthropocene.
Available online at
https://www.anthropocenemagazine.org/2018/09/amphibious-architecture.

Bamboo House India (2017)
Constructing a Bamboo House (Ground) – Process.
Available online at
https://www.youtube.com/watch?v=w9pz9HEI6D

Climate ADAPT (2023)
F*loating and amphibious housing.*
Available online at
https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/floating-and-amphibious-housing/#success_factors.

English, Elizabeth C. (2016)
Amphibious Architecture.
Where Flood Risk Reduction meets Climate Change Adaptation.
Available online at
https://www.munichre-foundation.org/content/dam/munichre/foundation/publications/2016_IMC_Day3_PS6%20Presentation%20English.pdf/_jcr_content/renditions/original./2016_IMC_Day3_PS6%20Presentation%20English.pdf.

13 | Consolidation of structures

Environmental impact	2/3
Risk protection	2/3
Durability	1/3
Affordability	2/3

Intro

The consolidation of structures on the shelter/block level is directed at a single building or housing cluster. Where the elevation of shelters is not possible, consolidating interventions can mitigate the impact of floods on the built infrastructures. Such small-scale interventions include dry and wet floodproofing as well as permanent flood walls and levees.

Dry floodproofing focuses on protecting the walls and openings of a building against the impact of incoming water. The goal is that the water cannot enter the structure. In the context of dry floodproofing, the use of sacrificial layers is important. They are designed to be 'sacrificed' or replaced after flood events. The goal is to protect and mitigate the damage to the more essential parts of the shelter while reducing repair costs. Sacrificial layers include interventions such as outer wall layers, door-protection gates, flood-resistant coatings, watertight doors, and walls, or temporary flood barriers such as sandbags *(See also measure [14])*. The process of wet floodproofing means allowing floodwater to enter the built infrastructure without the risk of damage. Such interventions include using flood-resistant materials, protected utilities, or openings in the structure.

Manent floodwalls and levees small, permanent floodwalls (made from concrete or steel) and levees (made from earth) are placed along the riverbanks to protect the adjacent built infrastructure from flooding. Levees can also be erected around the shelter or block where the structures are most prone to flooding or ponds. Watertight materials for these barriers include clay, mud, concrete, masonry, or steel.

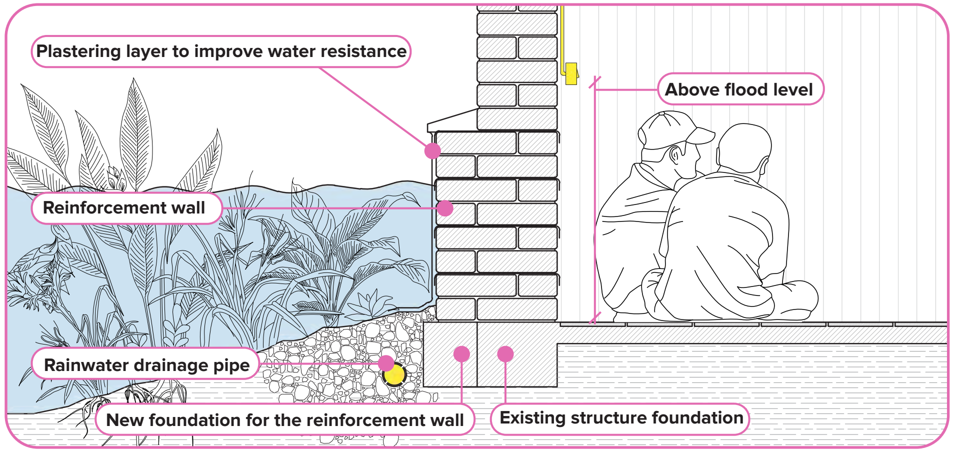
Benefits and Risk

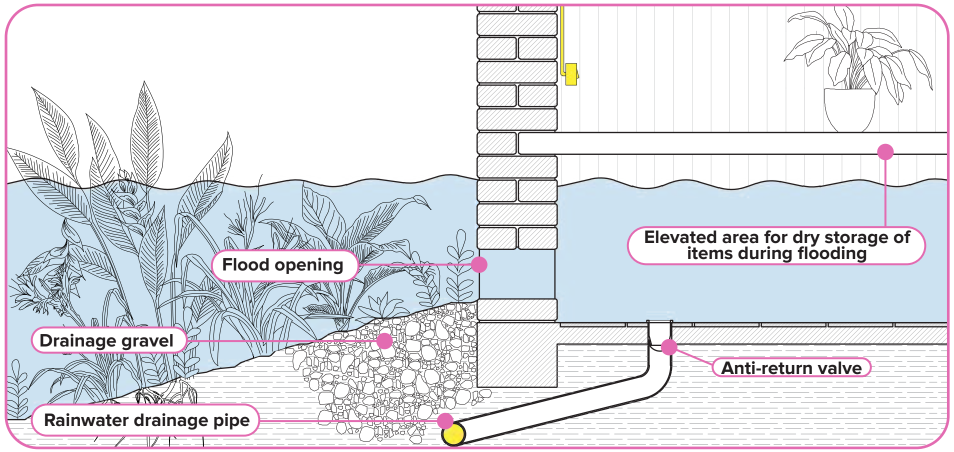
The benefits of dry and wet floodproofing are that they are comparatively less expensive than other retrofitting interventions. However, wet and dry floodproofing can have the disadvantage that they require regular maintenance and that, despite the interventions, evacuation is needed during floods. In addition, wet floodproofing can lead to contamination inside the buildings by sewage or chemical materials that can be part of the floodwaters. It needs a lot of cleaning and can result in uninhabitable shelters for a period of time.

Good practice

Sacrificial Layers In Bangladesh

In Bangladesh, Caritas led a shelter response project for refugees from Myanmar. Among other measures, the project that was carried out in 2018, worked with sacrificial layers in the camps while fostering local building traditions and shelter solutions. However, the project also looked at the improvement of housing conditions and provided recommendations for shelter response, for example, after the monsoon. In this light, one finding is that using cement screed to plaster mud walls is not a good idea because the materials do not hold together, and with the cement, the mud cannot dry since it is not permeable to humidity.





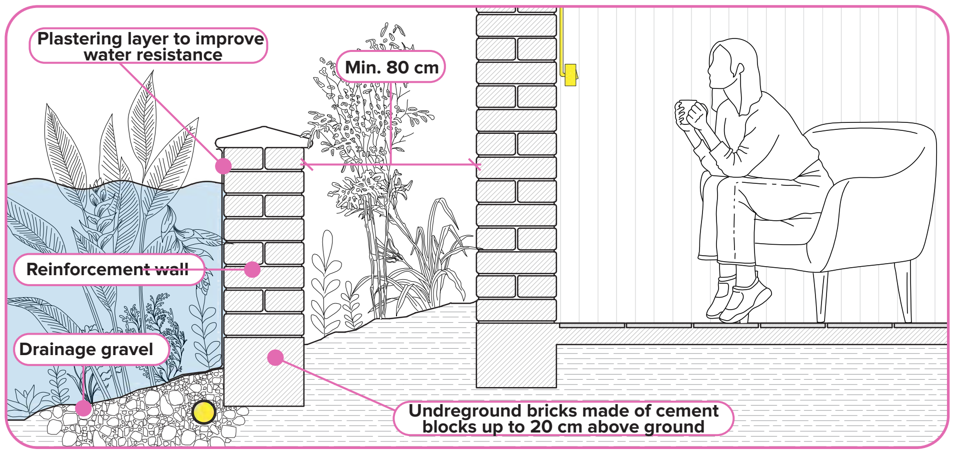


Fig. 11: *Traditional house in Bangladesh with a double sacrificial layer. J. Horta, CRAterre, 2018.*

Fig. 12: *Structure consolidation through reuse in the refugee camps. E. Cauderay, CRAterre, 2019.*

Fig. 13: *Structure consolidation through reuse in the refugee camps. E. Cauderay, CRAterre, 2019.*

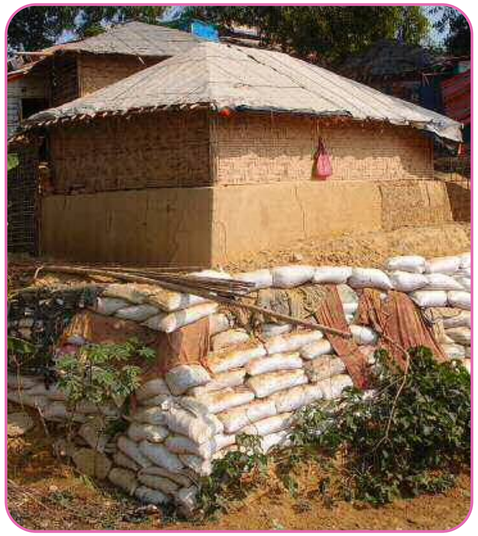


Fig. 14: *Structure consolidation in refugee camps sometimes requires a lot of reinforcement. E.Cauderay, CRAterre, 2019.*

Serlet, Murielle (2020)
Study on shelter response of Caritas Bangladesh for the Forcibly-Displaced Citizens of Myanmar. 2018. Available online at https://craterre.hypotheses.org/2498, updated on 2020.

Ullal, André; Estrella, Xavier (2021)
South Sudan - State-of-the-Art on Flood Resilient Shelters.

FEMA (2021)
Wet Floodproofing. Available online at https://www.fema.gov/glossary/wet-floodproofing, updated on 9/29/2023:01:09.

FloodWise (2023)
Dry Floodproofing (Dry Floodproofing). Available online at https://floodwise.ca/protect-your-home-business/floodproofing/dry-floodproofing/.

Overview of Criteria

Type of Intervention:
Engineered, hybrid.

Scale of Intervention:
Shelter-Plot-Block.

Materials:
Clay, mud, concrete, brick masonry, steel, plastic/geotextile sheets (selection)

Environmental Impact:
NA

Targeted Natural Hazard:
Pluvial Flood, Coastal/Riverine Flood.

Targeted Vulnerable Assets:
Buildings.

Strategy Type:
Reduce Asset Vulnerability.

Implementation Time:
Short (1 day - 1 month).

Effect Duration:
Short-term (<1 year), Medium-term (1 year to 10 years).

Investment Costs:
Low

Maintenance Costs (yearly):
Medium (10-50%)

14 | Temporary flood barriers

Environmental impact	2/3
Risk protection	1/3
Durability	1/3
Affordability	3/3

Intro

Temporary flood barriers describe pre-installed and removable flood protection systems placed at building entries, yards, pathways, or roads, among other locations. They come into use when immediate responses are needed and/or permanent flood protection measures do not suit the context-specific technical, economic, or environmental resources. The temporary barriers or floodwalls can come in the form of panels, containers, or tubes filled with earth and sand, among other fillings.

Benefits and Risk

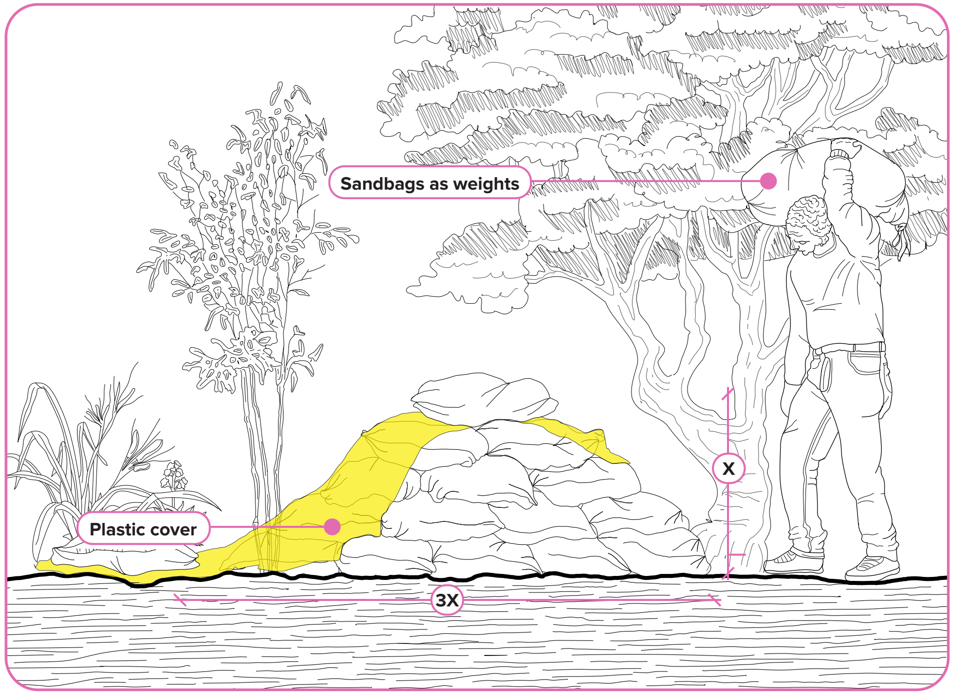
Although the temporary flood barriers are more affordable, of higher acceptance, and easier to install, they are also more prone to operational failure. A possible risk of temporary flood barriers can be the redirection of floodwaters which again increases the flood risks downstream of where the barriers have been installed.

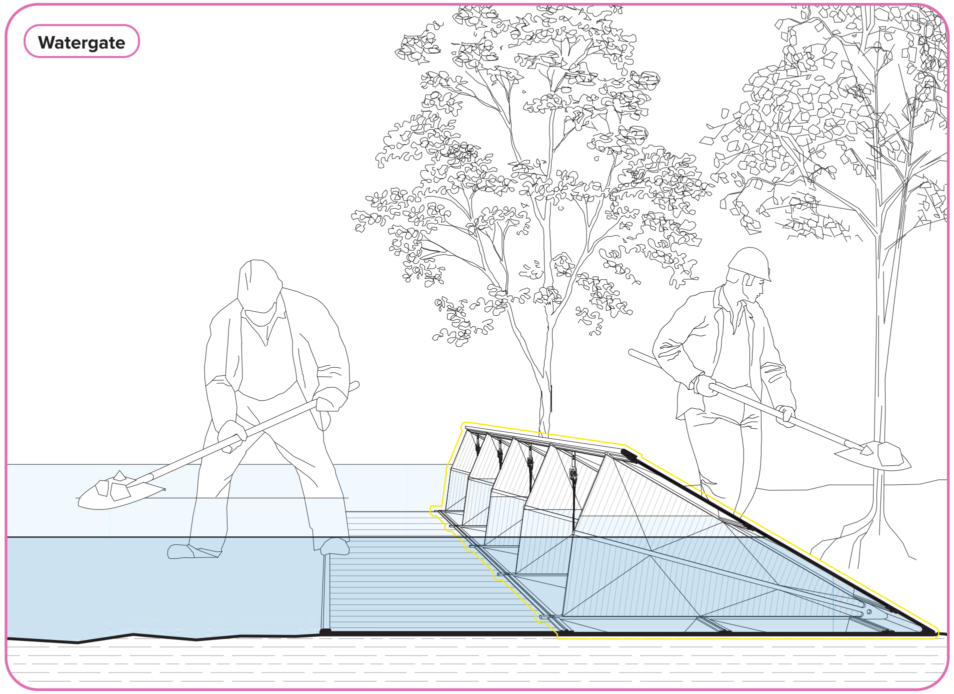
Good practice:

a1. Flood Bags (Sandless Sandbags)
This design example introduces a small-scale and temporarily installed flood barrier with the same functions as a sandbag but less heavy and without sand filling. Before coming into use, the flood barriers are flat, compact and lightweight bags. Once they meet water, they swell up to a weight of 15 kilogram in 10 minutes. The easily stackable and degradable bags are then able to divert the water and to absorb up to 10 liters. The length of the intervention ranges from 1.5m to 5m and can be implemented in refugee camp contexts, particularly in favor of dry proofing the settlements in the face of less severe flooding. They can be left in space for up to 6 months.

a2. Water-Gate
The easy-to-install water-gates control flood water. To stabilize themselves, the gates use the flood's pressure. The measure is a more expensive, but reusable and lighter than sandbags. Nevertheless, the installation is likely not to withstand the same flows as sandbags and should be used especially in the upstream end of the inundated area where there is no high waterflow. The impact area of a watergate reaches from a single house to an entire area *(Design 1st 2021).*

a3. Use of Low-tech sandbags in Cox's Bazaar, Bangladesh
In hilly terrain, heavy rains and flooding go hand in hand with landslides. As a result, assets need to be protected and slopes stabilized. In Cox's Bazar, where durable solutions are not allowed, low-tech protection measures with sandbags have been prioritized to solve issues. They present a quick and cheap solution but require heavy maintenance and/or frequent replacement. Their durability depends on bags and filling materials.





Design 1st. (2021)
5 New Flood Prevention Products.
Available online at
https://www.design1st.com/5-innovative-flood-prevention-products-replace-sandbags/.

IOM UN Migration (2020)
Site Improvement Catalogue.
Available online at
https://www.humanitarianlibrary.org/resource/iscg-site-improvement-catalogue.

The Associated Programme on Flood Management (2012)
FLOOD PROOFING. INTEGRATED FLOOD MANAGEMENT TOOLS SERIES. Available online at
https://www.floodmanagement.info/publications/tools/APFM_Tool_15.pdf.

Overview of Criteria

Type of Intervention:
Engineered, hybrid.

Scale of Intervention:
Shelter-Plot-Block, Settlement.

Materials:
Sand, Soil, Geotextiles, Panels (Materials vary depending on the barrier design, often fully pre-designed and ready to use)

Environmental Impact:
Positive environmental impacts of temporary flood barriers include the decrease of erosion due to floodwater diversion or stabilizing riverbanks. At the same time, some flood barriers can contain polluted floodwaters within a limited area and minimize the spreading of contamination to further areas. On the other hand, negative environmental impacts of flood barriers can lead to the (temporary) disruption of habitats and ecosystems such as movement hindrance of species.

Targeted Natural Hazard:
Pluvial Flood, Coastal/Riverine Flood.

Targeted Vulnerable Assets:
Buildings, transport.

Strategy Type:
Reduce Asset Vulnerability.

Implementation Time:
Short (1 day - 1 month).

Effect Duration:
Short-term (<1 year)

Investment Costs:
Low

Maintenance Costs (yearly):
Low (<10% investment costs)
Usually there is no maintenance involved concerning the use of temporary flood barriers

15 | Green roofs and walls

Environmental impact	3/3
Risk protection	1/3
Durability	2/3
Affordability	2/3

Intro

Green roofs are vegetated installations on top of a building or another built structure. Depending on the building type, size, and strength of the building structure, the installations can range from simple, low-cost green roofs to high-cost and complex roof gardens. Similarly, green walls are vertical, vegetated installations along any kind of wall. They are particularly favored in areas where there is limited space for planting on the ground. Green roofs and walls can support flood mitigation by slowing down the waterflow on the roof and, for example, by avoiding the gutters to spill over. They are best combined with other measures such as rainwater harvesting *(see Measure [09])*.

Benefits and Risk

Green roofs are multi-functional. They mitigate and absorb precipitation and stormwater, especially in the event of less intense but frequently returning rain. Green roofs can reduce air pollution and heat islands. Additionally, they support microclimates and save energy due to their cooling effect. That is also because the cooling effect decreases the need for air conditioning. Green roofs are also able to foster amenity values through, for example, space provision for water harvesting, recreation, food production or education. Similar to green roofs, green walls reduce heat islands and mitigate the rainwater runoff from buildings. However, the mitigation effect concerning heavy rainfall is less effective than the one of green roofs.

Design example

Green roofed containers

Green roofed containers can be a design option for shelter in refugee camps. Transitional shelters, including the ones made from containers, can be equipped with green roofs that again provide biodiverse new habitats and space for potential food production. Depending on the local context, the green roof includes a layer of filtration materials, soil, and native vegetation. The common size of (reused shipping) containers is approximately 6 x 2.4 meters *(Full Circle Design n.d.)*.

Good practice

The UNHCR Domiz Camp in Northern Iraq hosts over 40,000 Syrian refugees. Together with a landscape designer, the UNHCR created a greening strategy which included the installation of Syrian plants such as roses, pomegranate or lemon trees, also in the form of a green wall. The wall included vertically installed tin cans and plastic bottles for gardening that can absorb water from small rain events *(Padoan 2018)*.

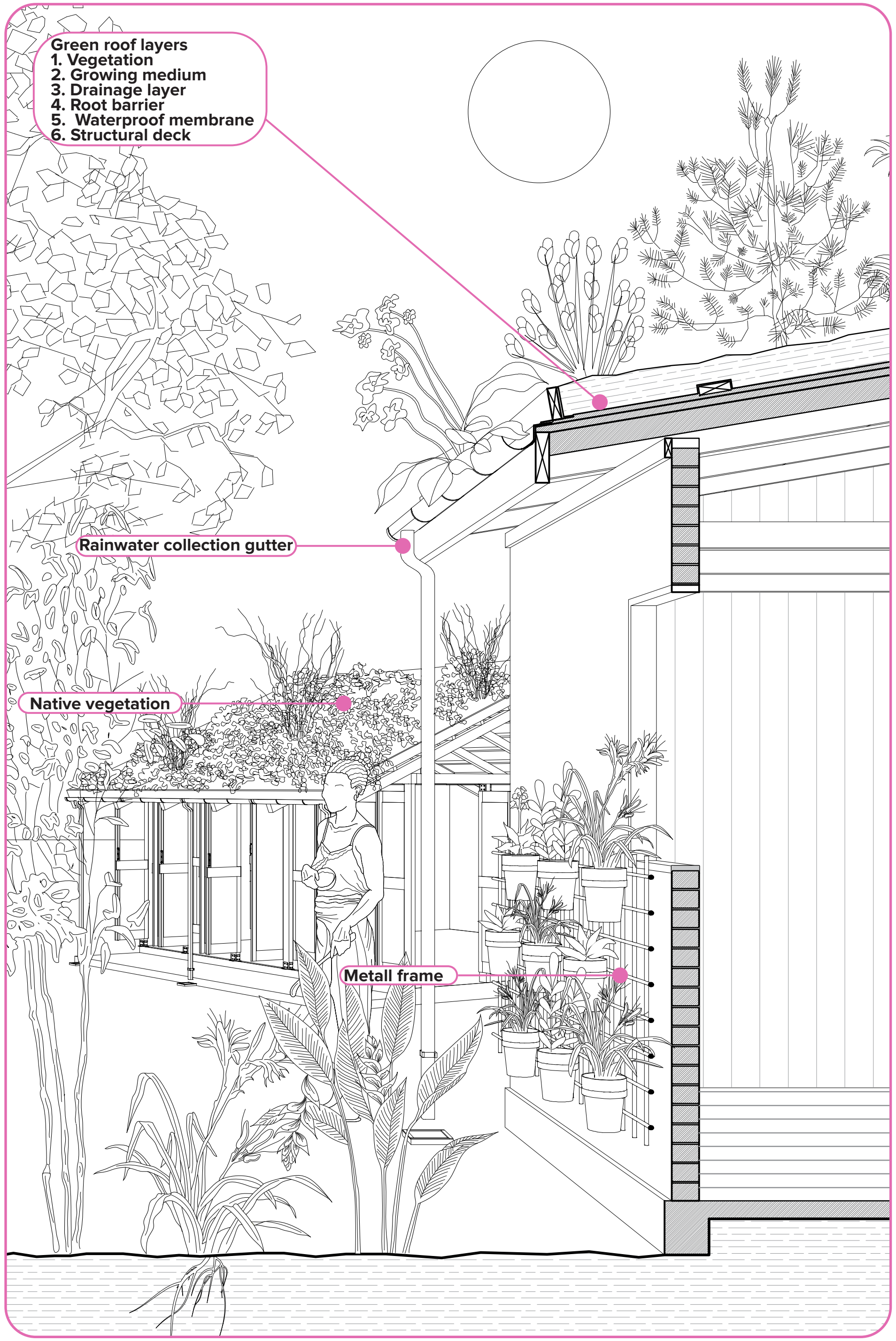


Fig. 15: *Design of a Green Roofed Shipping Container. Beaumé and Pabón 2023 based on Full Circle Design and Illustration n.d.*

Green Roof Shelters Ltd (2022)
The Green Roof Shelters Container family... In The Green Roof Shelters. Available online at *https://greenroofshelters.co.uk/green-roof-shelters-container-family/.*

Naturally Resilient Communities: USING NATURE TO ADDRESS *FLOODING. Available online at* *http://nrcsolutions.org/.*

Padoan, Laura (2018)
Seeds of hope: Chelsea Flower Show inspires refugee gardeners Lemon Tree Trust's garden reflects the hidden beauty in refugee camps. In UNHCR USA. Available online at *https://www.unhcr.org/news/latest/2018/5/5b05755b4/seeds-of-hope-chelsea-flower-show-inspires-refugee-gardeners.html.*

Ruangpan, L.; Vojinovic, Z.; Di Sabatino, S.; Leo, L. S.; Capobianco, V.; Oen, A. M. P. et al. (2020)
Nature-based solutions for hydro-meteorological risk reduction: a state-of-the-art review of the research area. In Natural Hazards and Earth System Sciences 20 (1), pp. 243–270. DOI: 10.5194/nhess-20-243-2020.

Overview of Criteria

Type of Intervention:
Hybrid.

Scale of Intervention:
Shelter-Plot-Block

Materials:
Wood, soil, waterproof membrane, drainage and filtering, growing media (soil), irrigation & plant materials, (reused shipping containers), painting

Environmental Impact:
Green roofs (and walls) can function as new habitats for insects, birds, or other animals which increases the local biodiversity. The vegetation might improve the air quality by carbon dioxide absorption and foster energy savings (see Benefits and Risks). Although the environmental impact of green roofs is generally positive, there can be reverse effects by, for example, introducing non-native or invasive plant species.

Targeted Natural Hazard:
Pluvial Flood.

Targeted Vulnerable Assets:
Buildings.

Strategy Type:
Reduce Hazard Magnitude, Reduce Asset Vulnerability.

Implementation Time:
Medium (1 month - 1 year).
The implementation time of green roofs usually ranges from several weeks to a few months. However, the timeframe highly depends on factors such as site-specificity, weather conditions, logistics, the roof size, the structure's complexity, the local availability of materials, and the expertise in installing green roofs.

Effect Duration:
Long-Term (>10 years).
Although the waterproof membrane of a green roof has a life expectancy of around 40 years, regular maintenance of the installation, the plants and soil are necessary.

Investment Costs:
Low.
In the United States, it costs approximately $10-$25 to install a square foot of a green roof. The implementation of a green roof on top of an existing structure that needs reinforcement could include more costs. Nevertheless, there is evidence that the investment in a green roof will pay back after a short period of time, not least due to the energy savings enabled by the green infrastructure.

Maintenance Costs (yearly):
Low (<10% investment costs).

IV. Nature restoration

Introduction and summary: Nature restoration

Humanitarian settlements draw on their surrounding natural resources. As a result, settlement planning should acknowledge the significance of functioning natural ecosystems and their role in mitigating natural hazards. This chapter addresses the importance of nature restoration and nature-based solutions for flood risk management as alternative or complementary interventions to engineered and hybrid measures. It introduces four types of nature restoration:

1. Wetlands (*see Measure [16]*)
2. Tree Planting and Forest Preservation (*see Measure [17]*)
3. The Restoration of Sand Dunes (*see Measure [18]*)
4. Floodplain Restoration (*see Measure [19]*)

Nature-based Solutions (NbS) describe an umbrella term for interventions that protect, manage, and restore (semi-) natural ecosystems. In terms of NbS for flood risk reduction, concepts such as:

a. Green Blue Infrastructures,
b. Ecosystem-based Adaptation, or
c. Ecosystem-based Disaster Risk Reduction

are relevant to mention. In most cases, NbS and nature restoration are implemented upstream (and downstream) of an area prone to flood risks. It is, therefore, essential to consider the local and regional context of nature restorations for flood risk mitigation.

16 | Wetlands

Environmental impact 3/3
Risk protection 2/3
Durability 3/3
Affordability 2/3

Intro

Wetlands are areas that show moist or saturated surface conditions throughout the year or during parts of it. Mostly linked to groundwater-, stream- or coastal systems, wetlands infiltrate, clean, store, and slowly release water. Wetland types range from upland rain-fed wetlands and wet grasslands to peatlands. They also include coastal and river-fed floodplains. Restoring wetlands is, therefore, closely linked to floodplain restoration *(see Measure [19])*. Due to their capability to store and manage water, wetlands are also measures for surface water management *(see Category II)*.

Benefits and Risk

Highly important for the hydrological cycle, wetlands positively affect the surrounding soils, vegetation, and wildlife. They serve as a natural sponge, which enables them to reduce riverine and pluvial flood volumes. The moist ecosystems can mitigate droughts by slowly releasing water flows during dry periods. Coastal wetlands are buffers from extreme weather events such as storms or waves. Healthy salt marshes, coral reefs, mangroves, or seagrass can play an essential role here. Wetlands, especially peatlands, mangroves, and seagrass, function as highly effective carbon sinks by absorbing and storing greenhouse gases.

On the other hand, draining wetlands causes a massive release of stored CO2. Another critical aspect is that, depending on context and type, wetlands can have less storage capacity and, therefore, even increase water overflows or flooding, such as in the case of the all-year saturated upland rain-fed wetlands. Finally, land use changes and coastal, rural, or urban development may harm and transform the hydrology of the location.

Good practice

Originally a natural oasis in a hot and dry desert environment, the Azraq wetland and basin have become the subject of disproportionate water overuse and drilling since 1980. That is especially due to urban expansion and agricultural practice, causing around 25 km2 of wetland to dry up and increasing floods in the area. The wetland lies adjacent to the town of Azraq and the Al-Azraq Refugee Camp, which is home to around 38’000 Syrian refugees.

The massive depletion encouraged the restoration of the wetland in the past 30 years. In 2020, three water pools that had existed earlier in the reserve were rehabilitated. Yet the pools faced an increase in phosphorus rate because non-native fish and algae had become rampant. This made the water inhabitable for endemic species such as the Azraq killifish. Therefore, the three pools were purposely dried out, and their slopes strengthened with topsoil while controlling the bulrush and reeds. Afterward, the small basins were again supplied with water. In addition, the native killifish were reintroduced to the pools, attracting the common kingfisher and other migratory birds.

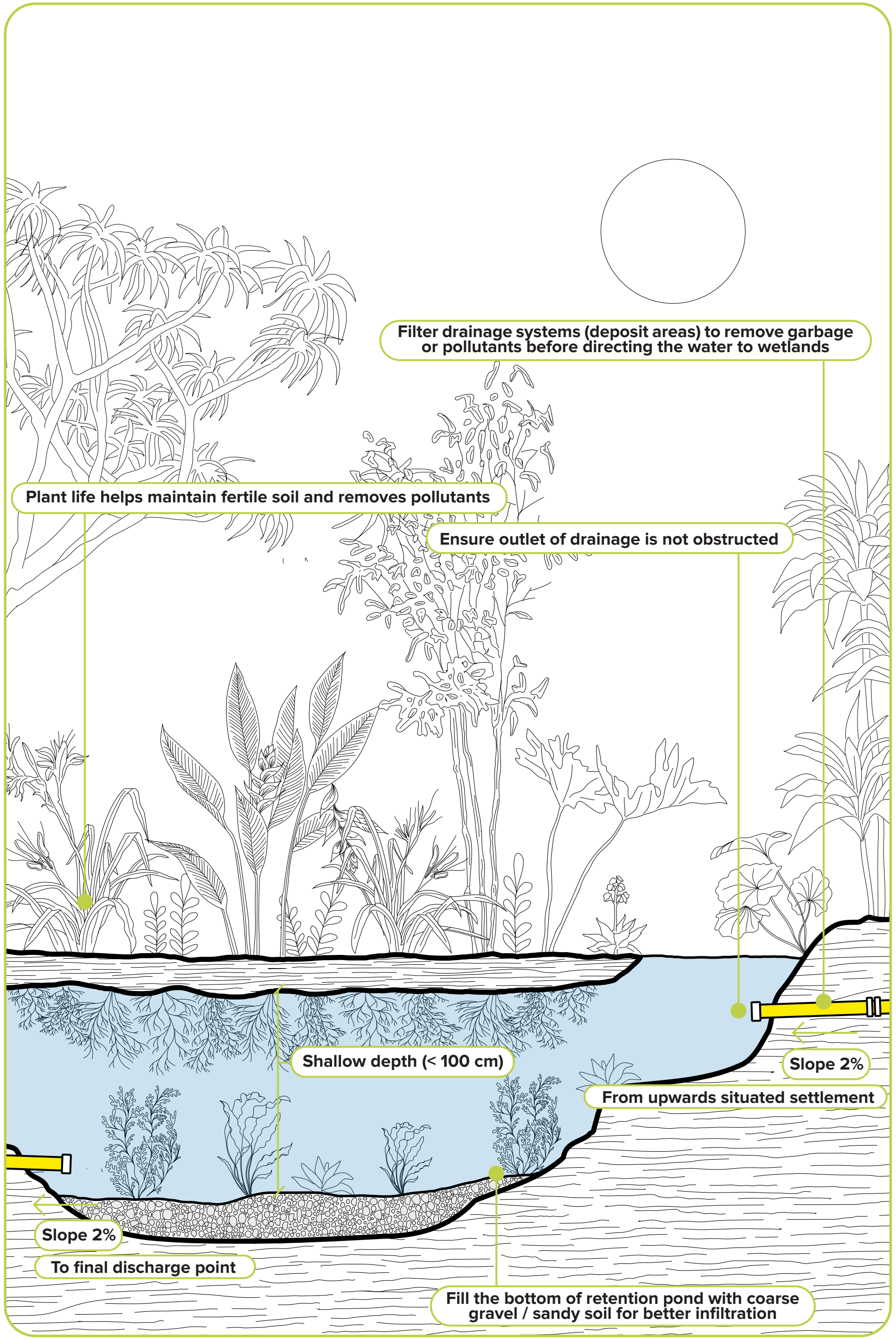


Fig. 16: *Bird hides pool three months after the first restoration phase of the Azraq wetlands in 2020. Hazem Hreisha 2020.*

Overview of Criteria

Type of Intervention:
Nature-based, Hybrid.

Scale of Intervention:
Supra-settlement.

Materials:
Wood, (Sandy) Soil, Coarse Gravel, Native Vegetation.

Environmental Impact:
Wetlands store great amounts of carbon and have, therefore, a negative CO2 Footprint. In return, the destruction of wetlands can release great amounts of carbon. For example, 10 percent of global carbon emissions result from draining or burning peatlands *(Ramsar 2019)*.

Targeted Natural Hazard:
Pluvial Flood, Coastal / Riverine Flood.

Targeted Vulnerable Assets:
Buildings, Transport.

Strategy Type:
Reduce Hazard Magnitude.

Implementation Time:
Medium (1 month - 1 year)

Effect Duration:
Long-term (>10 years).

Investment Costs:
Medium.
Wetland restoration projects differ in cost depending on their location, landscape, and complexity. Example: A restoration project in Nova Scotia, Canada, describes restoration costs of $3-10 Canadian Dollars per square meter of restored wetland (Nova Scotia n.y.).

Maintenance Costs (yearly):
Low (<10% investment costs).

Calow, Roger; Mason, Nathaniel; Tanjangco, Beatrice (2021)
Nature-based solutionsfor flood mitigation.
Available online at
https://bracc.kulima.com/sites/default/files/2022-03/NBS%20for%20Flooding%20discussion%20paper.pdf.

Mediterranean membership network of wetland managers (2021)
A success story: restoration of the Azraq Wetland, Jordan.
Available online at
https://medwetmanagers.net/a-success-story-restoration-of-the-azraq-wetland-jordan/.

Nova Scotia: Wetland Compensation - What's Required and What Are My Options?
Available online at
https://novascotia.ca/nse/wetland/docs/Wetland_Compensation.pdf.

Phadtare, Imelda (2020)
Disaster Risk Reduction and mitigation: green growth in Jordan's humanitarian sector.
Available online at
https://www.ecoltdgroup.com/disaster-risk-reduction-and-mitigation-green-growth-in-jordans-humanitarian-sector/.

Ramsar (2019)
Wetlands: The key to coping with climate change.
Available online at
https://www.ramsar.org/sites/default/files/documents/library/wwd19_handout_e.pdf.

17 Tree planting and forest preservation

Environmental impact 3/3
Risk protection 2/3
Durability 3/3
Affordability 2/3

Intro

Trees reduce the volume of the stormwater surface runoff in three steps: First, the leaves, branches and trunks catch and intercept the raindrops. The water then either trickles off into the ground, or it evaporates back into the air. The rate of the interception, infiltration, surface runoff reduction and, therefore, the flood response increase with the forested area in relation to the catchment size. In this regard, the measure is also linked to surface water management *(see Category II).*

Mangrove forests are a specific type of trees for flood risk mitigation. They are multifunctional ecosystems that mainly occur along sheltered tropical and subtropical coasts. As for flood risk mitigation, mangroves reduce the wind height, incoming waves, and the level of storm surges. In addition, they protect the coastline and control its erosion

Benefits and Risk

Next to mitigating the stormwater flow, trees comprise several other benefits. They reduce heat islands in built environments. Trees also absorb pollutants from the air, the groundwater and the soil, reduce high-frequency noise and, by that, tackle human health issues such as respiratory illnesses or mental distress.

With afforestation representing a form of ecological restoration, forests or single trees also support the local biodiversity. For example, the tree canopies of mangroves serve as bird nesting and resting grounds while fostering coral reefs and seagrass beds. They only can be planted in very specific contexts of natural environment and climate. Because mangroves commonly grow surrounded by half-salty water, the trees depend on adequate sea-surface and air temperature and may be fragilized by repeated flood events and other climatic effects.

Design example

Miyawaki pocket forests for flood risk mitigation
The pocket forests for flood risk mitigation of the organization SUGi describe 4 to 10-meter-wide patches of trees that form a barrier between a waterbody and the infrastructure that needs protection. The SUGi forests implemented around the globe are based on the Japanese Miyawaki forest planting technique, which is a special approach to highly dense forest planting with several layers of vegetation at different heights, combining shrubs, (sub-) trees, and canopy trees. Thanks to their density and strong root system, the pocket forests build a wall-like structure based on vegetation to shield the infrastructure from flooding (SUGi 2022).

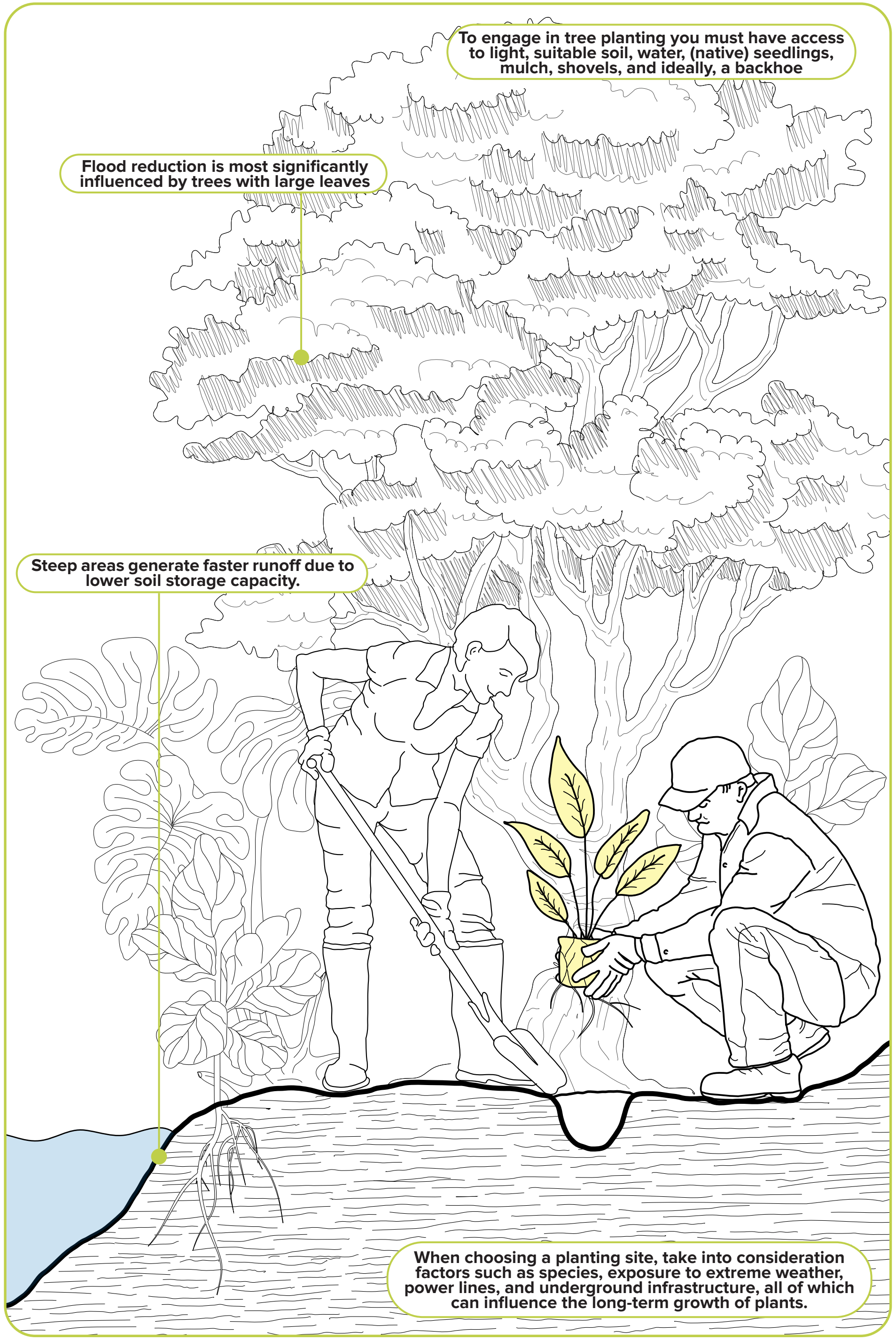


Fig. 17 and 18: *Example of a Miyawaki forest built by the SUGi team in Buea, Cameroon, before and 2.5 years after the tree planting. SUGi 2022.*

SUGi (2022)
Revive waterways and biodiversity in Cameroon. Available online at https://www.sugiproject.com/projects/bulu, updated on 9/29/2023:07:54.

UN Environment Programme (2020)
Celebrating International Mangrove Day: spare a thought for our coastal ecosystems. Available online at https://www.unep.org/news-and-stories/story/celebrating-international-mangrove-day-spare-thought-our-coastal-ecosystems.

Watson, Julia (2020)
Lo–TEK. Design by Radical Indigenism. Acadja Aquaculture of the Tofinu, Benin, p. 351-367.

Overview of Criteria

Type of Intervention:
Nature-based.

Scale of Intervention:
Supra-settlement.

Materials:
Soil, Water, Native seedlings, Mulch, Shovels, Backhoe.

Environmental Impact:
Forests, particularly mangroves, act as carbon sinks and serve carbon sequestration and nutrient cycling above and below the ground. However, this function comes with the risk of high carbon release in case of loss or deforestation of trees, especially mangroves.

Targeted Natural Hazard:
Pluvial Flood, Coastal/Riverine Flood.

Targeted Vulnerable Assets:
Land Cover.

Strategy Type:
Reduce Hazard Magnitude.

Implementation Time:
Short (1 day - 1 month).

Effect Duration:
Long-term (>10 years).

Investment Costs:
Low

Maintenance Costs (yearly):
Low (<10% investment costs)
Next to training local personnel, the maintenance (and its cost) includes the watering, pruning, thinning, debris removal, and disease inspection.

18 | Sand dune management and restoration

Environmental impact	3/3
Risk protection	2/3
Durability	3/3
Affordability	2/3

Intro

Dunes are natural flood barriers that protect the inland from the brunt of coastal floods and storm surges. The sandy ridges develop in parallel to the shoreline. Dunes change their size and shape due to tides, winds, storms, or heavy sea. In case of flooding, the health of the vegetation can decide upon the effectiveness of the dune's mitigation capacity.

The restoration of dunes includes the recovery of eroded areas and dune stabilization based on vegetation and fences. In general, the interventions that join the restorations of dunes should not disrupt the natural forming processes and the dune ecosystems. A careful assessment of the site before the implementation of measures is highly recommended.

Benefits and Risk

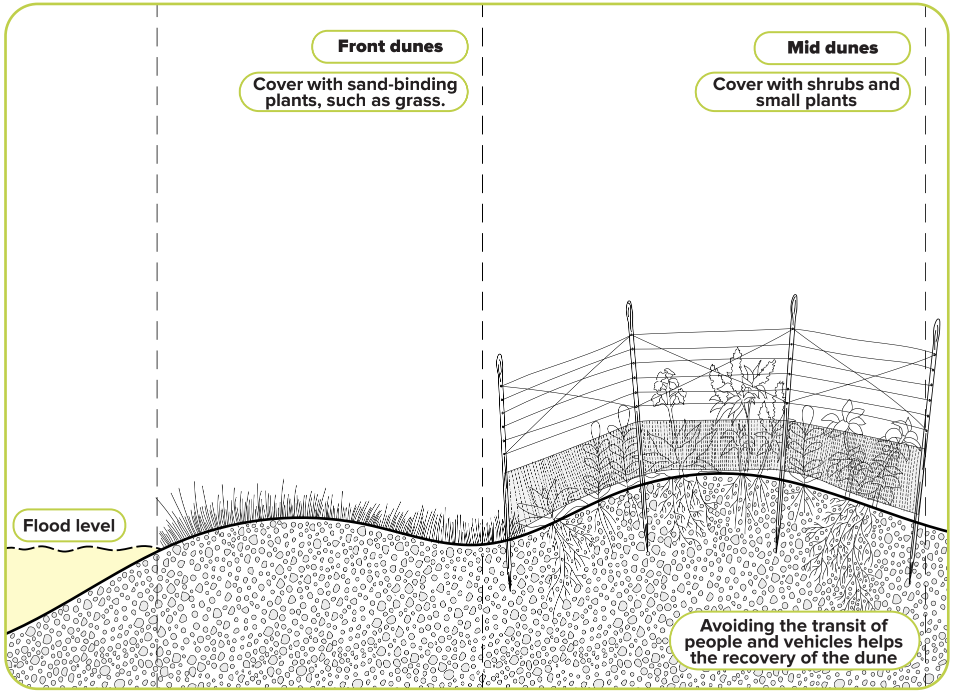
Compared to engineered dams, dune systems depend on more space between the shore and the developed inland to reach the highest efficiency. A sand dune with a narrow beach close to a developed area has a smaller flood mitigation impact than one with a wide and large beach. Overall, coastal development and increasing urbanization describe a severe threat for the health and effectiveness of dune systems.

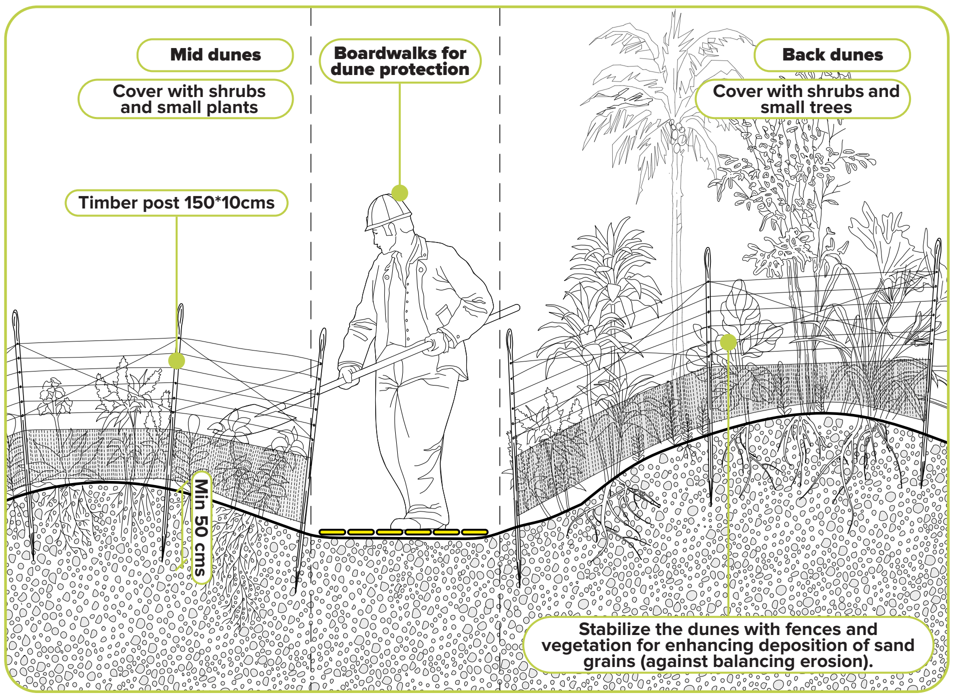
Good practice

Sand dune restoration in S. João Da Caparica, Portugal.
The Portuguese city of Almada lies at Atlantic coast. It faces sea-level rise, increasing erosion, the threat of storm surges, and extreme flooding. As a result, the project ReDuna was initiated in 2014 to prioritize dune restoration, coastal protection, biodiversity targets, and community awareness in the urban area of Almada.

After the destruction of the dune ecosystem due to winter storms, the project began with the dune restoration by installing willow, fences, pathways, and around 100'000 native plants along 1 km of the shore. After installing these measures within 6 months, a monitoring system continuously assessed the sand dune ecosystem. The Faculty of Science of Lisbon University, Center of Ecology led the monitoring which included, among other analyses, the site's geomorphological changes via GPS. After four years of monitoring, the results showed increased biodiversity, more stability in sediment transfer, and that the planted vegetation had formed a dense and effective root system (as deep as four meters) for dune stabilization. The Storm Emma in 2018 proved the regained efficiency of the sand dunes.

In addition, the local community was involved in the design process and maintenance campaigns. The actions for maintenance *(including the removal of alien species)* take place after each summer and storm season. The EU Structural and Cohesion Fund financed the structural interventions at the beginning of the project. The municipality then paid for the monitoring and human resources *(Connecting Nature 2020).*





Overview of Criteria

Type of Intervention:
Nature-based.

Scale of Intervention:
Supra-settlement.

Materials:
Native Vegetation (For example, dune-forming perennial grasses such as sand couch, sea Lyme or marram grass), fences, (wooden) posts, wood for boardwalks.

Environmental Impact:
Sand dune restoration supports the protection of ecosystems and biodiversity. In addition, healthy sand dunes help mitigate coastal erosion and storm surges.

Targeted Natural Hazard:
Coastal/Riverine Flood.

Targeted Vulnerable Assets:
Buildings, Transport, Land Cover.

Strategy Type:
Reduce Hazard Magnitude.

Implementation Time:
Medium (1 month - 1 year), Long (<1 year).

Effect Duration:
Medium - term (1 year to 10 years).

Investment Costs:
Low, Medium.

Maintenance Costs (yearly):
Low (<10% investment costs), Medium (10-50%).

Climate ADAPT (2023)
Dune construction and strengthening.
Available online at
https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/dune-construction-and-strengthening/#implementation.

Connecting Nature (2020)
ReDuna - Restoration of S. João da Caparica Sand Dunes.
Available online at
https://connectingnature.eu/oppla-case-study/22495, updated on 9/29/2023:29:33.

Naturally Resilient Communities:
USING NATURE TO ADDRESS FLOODING.
Available online at
http://nrcsolutions.org/.
UKCEH; UK Sand Dune and Shingle Network and Dynamic

Dunescapes partners (2021)
The Sand Dune Managers Handbook. 1st ed.: Produced for the Dynamic Dunescapes (DuneLIFE) project: LIFE17 NAT/UK/000570; HG-16-08643.
Available online at
https://dynamicdunescapes.co.uk/wp-content/uploads/2021/07/Dynamic-Dunescapes-Sand-Dune-Managers-Handbook-June-2021.pdf.

19 Floodplain restoration

Environmental impact	3/3
Risk protection	2/3
Durability	3/3
Affordability	1/3

Intro

A floodplain is a low-lying, flat area of nutrient-rich sediment along the river. A river and floodplain together describe an integrated system. The floodplain enables the water body to transport floodwaters. As a result, upstream (and downstream) retention and expansion areas benefit flood risk mitigation and reduce water logging. However, floodplains face continuous degradation due to permanent flood barriers *(see Category I)*, urban and agricultural development, or river channelization. These changes have significantly affected the efficiency of floodplains as aquatic and terrestrial habitats, water qualifiers and natural providers of flood protection. The rehabilitation or conservation of effective floodplains is, therefore, an essential intervention for flood risk mitigation in humanitarian settlements. Floodplain restoration is closely linked to wetland restoration *(see Measure [16])*.

Benefits and Risk

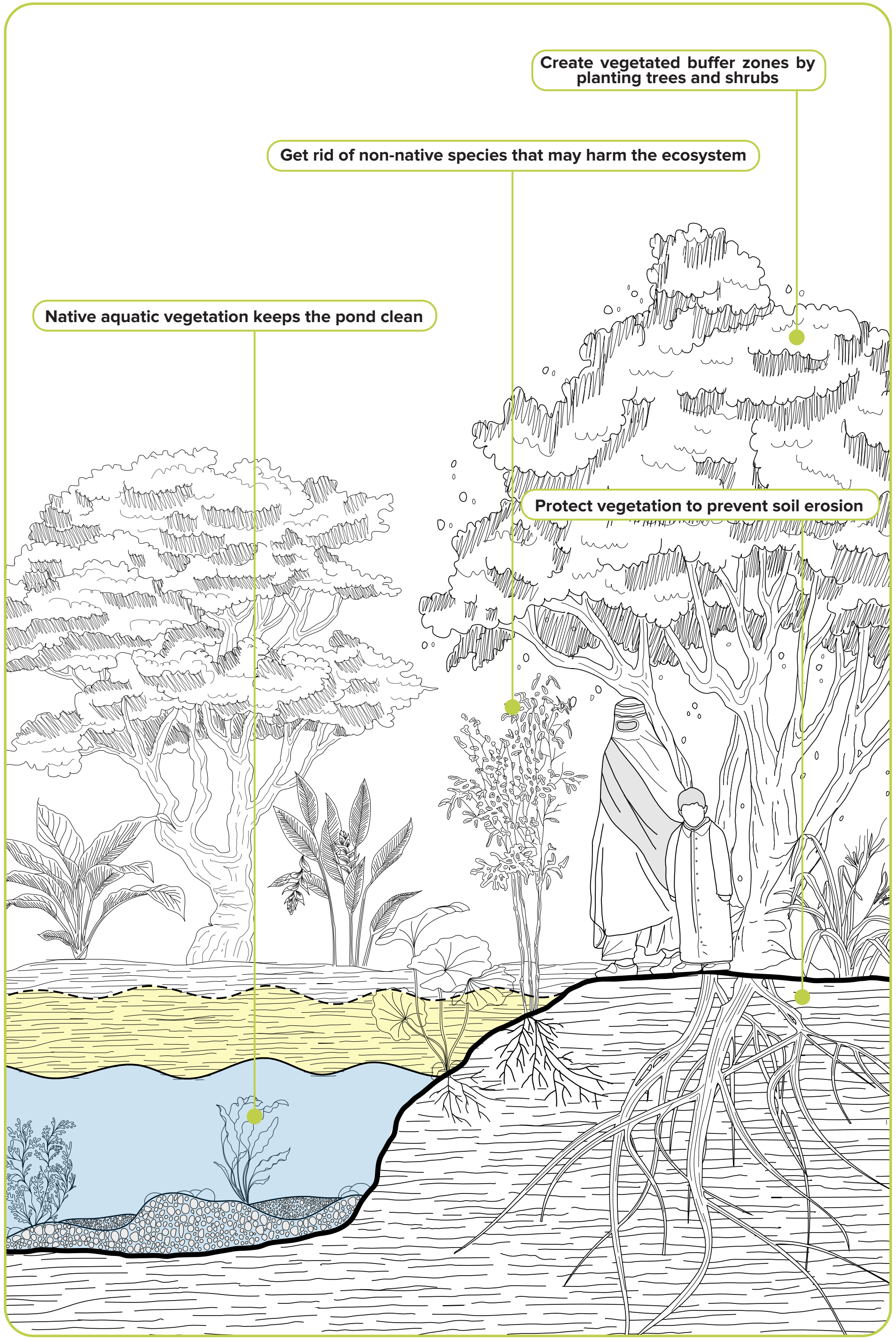
In case of a river spillover, the floodplain slows the water rise. It provides a form of a temporary reservoir before feeding the water back to the river once the flood decreases. By reducing the speed of the flood, the floodplain also reduces downstream erosion, filters the water and improves the overall quality of the water body. Given that the inundation conveys sediments and nutrient-rich soil, the floodplains tend to be fertile and provide rich habitats for wildlife and vegetation. Nevertheless, the flood mitigation effect and the co-benefits of a floodplain depend on its shape, size and composition. In this light, the erection of levees, dams, or other structural measures may be counterproductive if they cut off the waterways from their floodplains. Such disconnection could lead to habitat loss and decreased flood risk reduction.

In general, humanitarian settlements should not be planned and built on or adjacent to floodplains to avoid increased flood risk. Buffer zones *(see Measure [20])* in refugee camps can support flood risk mitigation and floodplain conservation.

Good practice

3rd Rhône's correction, Switzerland

Levees *(see Measure [01])* describe one of the most expedient flood control methods, especially where space is scarce. However, due to their drawbacks *(e.g., aggravating risks in case of collapse)*, solely flow containment must be avoided. In Europe, where river restriction started several centuries ago, recent events show that the use of levees must be reconsidered. For example, for the Rhône River in Switzerland, the 3rd flood protection concept is in progress. The project ensures balanced goals between flood protection, biodiversity, and socio-economic constraints. Where levees cannot be avoided, the concept provides enough space for the river's expansion during flood periods. Such river widening shows similarities with the river restoration strategy. Today a large bunch of examples of river expansion may be found all over Europe, especially in the Netherlands.



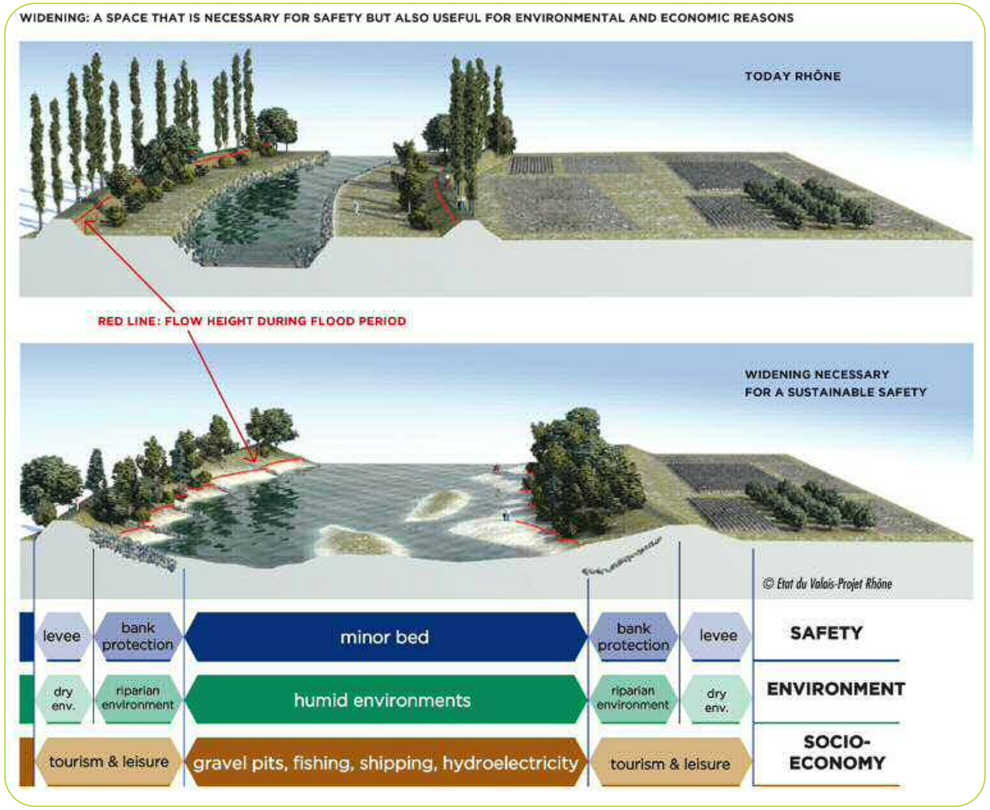


Fig. 19*: 3rd Rhône's correction. Etat du Valais 2015.*

Climate ADAPT (2022)
Rehabilitation and restoration of rivers and floodplains.
Available online at
https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/rehabilitation-and-restoration-of-rivers, updated on 9/29/2023:34:14.

NWRM, Natural Water Retention Measures (2015)
Floodplain restoration and management.
Available online at
http://nwrm.eu/measure/floodplain-restoration-and-management, updated on 9/29/2023:30:19.

Scnat Netzwerk (2023:31:33)
Floodplains: a natural system to preserve and restore
(EEA Report, 24/2019).
Available online at
https://scnat.ch/de/uuid/i/96de4fa4-ee4a-5f7e-9f07-ca302becfabf-Floodplains_a_natural_system_to_preserve_and_restore.

Overview of Criteria

Type of Intervention:
Nature-based.

Scale of Intervention:
Supra-settlement.

Materials:
Wood, Native Vegetation.

Environmental Impact:
Floodplains improve the overall water quality and can support the reduction of chemical and nutrient pollution. Due to their fertility, they provide rich habitats for wildlife and vegetation. As a result, floodplain restoration and rehabilitation can increase an area's biodiversity *(Scnat Netzwerk 2020)*. However, the processes of floodplain restoration *(e.g., removing invasive species)* can disturb the existing habitats over a short time period or change the water flow dynamics. At the same time, the restoration can introduce new invasive species. In the case of former pollution or contamination of floodplains, the redistribution of the substances is possible. Such disturbances should be considered and kept as minimal as possible.

Targeted Natural Hazard:
Coastal / Riverine Flood.

Targeted Vulnerable Assets:
Buildings, Transport, Technical Infrastructure.

Strategy Type:
Reduce Hazard Magnitude.

Implementation Time:
Medium (1 month - 1 year), Long (> 1 year).
In general, the restoration of ecosystems implies long and complex processes. Depending on the extent and local conditions, that might also be the case with rehabilitating floodplains. Public awareness and support are important in such processes since the long-term effect of the restored floodplain will pay off *(Climate Adapt 2022).*

Effect Duration:
Long-term (>10 years).

Investment Costs:
Medium, High.

Maintenance Costs (yearly):
Low (<10% investment costs).

V. Non-built measures and capacity building

Introduction and summary: Non-built measures and capacity building

The previous four categories aim to limit the magnitude of the hazard and the vulnerability of buildings and other assets through built and nature-based measures. Depending on the situation and the scale of the event, these solutions may not suffice. In case of particularly strong events or when other measures are not possible to implement, emergency planning's main goal is to limit casualties, including:

1. The relocation of plots or the entire settlement and the creation of buffer zones (*see Measure [20]*)
2. The planning of escape routes and community refugee (*see Measure [21]*)
3. The development of hazard maps, risk assessments and mitigation strategy (*see Measure [22]*)

Most often the community in the humanitarian settlement will take part in the building of mitigation measures and be in charge of their maintenance. Therefore, the solutions and techniques should align with the local context as it will enhance participation (*see Measure [22]*). In addition, capacity and risk awareness building of the population is a crucial factor in reinforcing the resilience of the communities and the organization of immediate risk responses (*see Measure [21]*).

20 Relocation and buffer zones

Environmental impact	1/3
Risk protection	3/3
Durability	3/3
Affordability	1/3

Intro

Relocation
One of the four main strategy types for flood risk mitigation *(see 1.2)* is the partial or full relocation of the refugee settlement. If the flood risk or (expected) damages turn unmanageable, a settlement or parts thereof can be shifted to another location. This strategy implies a long process of securing adequate land, equipping it, and organizing the move of population. When planning new zones or settlement, refer to the principles and guidance described in UNHCR's Masterplan approach. While planning the relocation, a possible intervention for limiting flood risk on the new location is to add buffer zones along the areas at flood risk.

Buffer Zones
Buffer zones designate protective areas between particularly flood-prone locations and the refugee settlement. These buffers should be based on comprehensive flood risk assessments, the local topography, and climatic conditions. Usually, the designated areas prohibit any form of (residential) buildings. They foster the absorption or diversion of floodwaters and can include measures like floodplains, wetlands, flood resilient agriculture or tree planting *(see Measures [16-19]);* bioswales and infiltration basins, or permeable pavements *(see Measures [08,10]);* as well as engineered barriers such as dikes and levees *(see Measure [01]).*
Programming the area with activities and informing the population about the risk are crucial to avoid that the planned buffer zones are used for construction at a later stage. Awareness raising campaigns *(see Measures [21] and [22])* should be repeated regularly for newcomers to be informed as well.

Benefits and Risk

The relocation of an entire settlement increases the overall safety and well-being of the inhabitants and can reduce or avoid significant damage to the built and technical infrastructure. Selecting a new location provides the opportunity to prioritize long-term safety based on comprehensive site and risk assessments in advance. Moreover, the new site can support improved sanitation and shelter structures.

However, relocations involve the repeated displacement of already displaced communities. The change of location might harm established social networks, the loss of livelihoods, and can lead to negative psychological and emotional consequences. The inhabitants of the affected refugee settlement should be comprehensively informed and involved in the relocation process.

Moreover, identifying a new area for the humanitarian settlement can take a lot of time and include a complex process and logistics, including negotiations with local authorities. The relocation can also lead to the (short-term) disruption of essential services *(e.g., healthcare, education).* Lastly, the environmental impact of relocations and setting up new settlements can be significant.

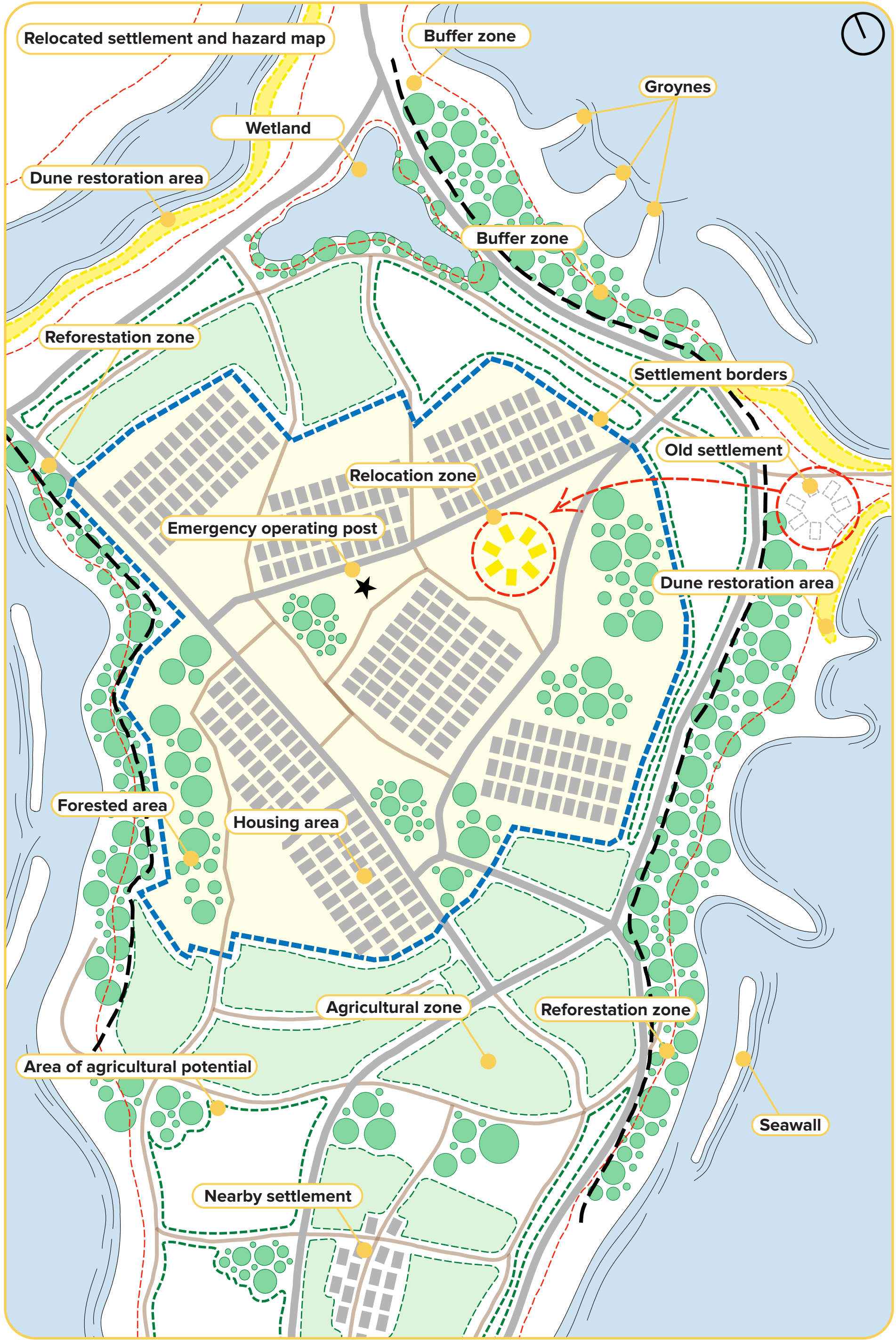


Fig. 20 and 21: *Buffer Zones in Cox's Bazar. Nadia Carlevaro, UNHCR n.d.*

Good practice

Relocation of settlements in a flood - prone area in the Leitchuor refugee camp, Ethiopia.
The "Leitchuor" refugee camp in the Ethiopian Gambella region opened in late 2013 to host South Sudanese people fleeing from the violence in their country. Situated in a flood-prone area, the camp was severely flooded during the next rainy season in 2014. The only suitable solution was a permanent relocation of the people. A safer location was identified several kilometers away and refugees were relocated to the new settlement named "Jewi".

Buffer zones in cox's bazar refugee settlement, Bangladesh.
Cox's Bazar hosts over 800'000 Rohingya refugees in the highly-dense settlement of Kutupalong, comprising 26 camps. The camps are located on hilly terrain prone to high risks of flooding and landslides. To mitigate the impact of floods, the lowlands most at risk of flooding were redefined as buffer zones and for agricultural use. In some planned camps (e.g, Camp 4 Ext.) steep terrain has been consolidated with nature-based solutions to create slow drains and outline buffer zones from living areas (UNHCR n.d).

Sphere (2018)
The Sphere Handbook. Fourth edition. Geneva Switzerland: Sphere Association.

Overview of Criteria

Type of Intervention:
Non-structural.

Scale of Intervention:
Shelter-Plot-Block, Settlement

Materials:
NA.

Environmental Impact:
Depending on the local context, the relocation of a refugee camp due to flooding can include land clearances, excavations, leveling, or deforestation. This process can lead to the loss or disruption of the local biodiversity, wildlife habitats and ecosystems, while invasive species might occur. Setting up a new settlement requires also more water and energy resources and can lead to increased amounts of waste and the contamination of the surrounding nature. Relocation processes should always be based on comprehensive environmental impact assessments prior to selecting the new location and setting up the settlement.

Targeted Natural Hazard:
Pluvial Flood, Coastal/Riverine Flood.

Targeted Vulnerable Assets:
Buildings, Transport, Technical Infrastructure.

Strategy Type:
Relocate, Reduce Asset Vulnerability.

Implementation Time:
Medium (1 month - 1 year), Long (> 1 year).

Effect Duration:
Short - term (<1 year), Medium - term (1 year to 10 years), Long - term (>10 years).

Investment Costs:
High.

Maintenance Costs (yearly):
NA.

21 Preparedness and capacity building

Environmental impact	3/3
Risk protection	2/3
Durability	2/3
Affordability	3/3

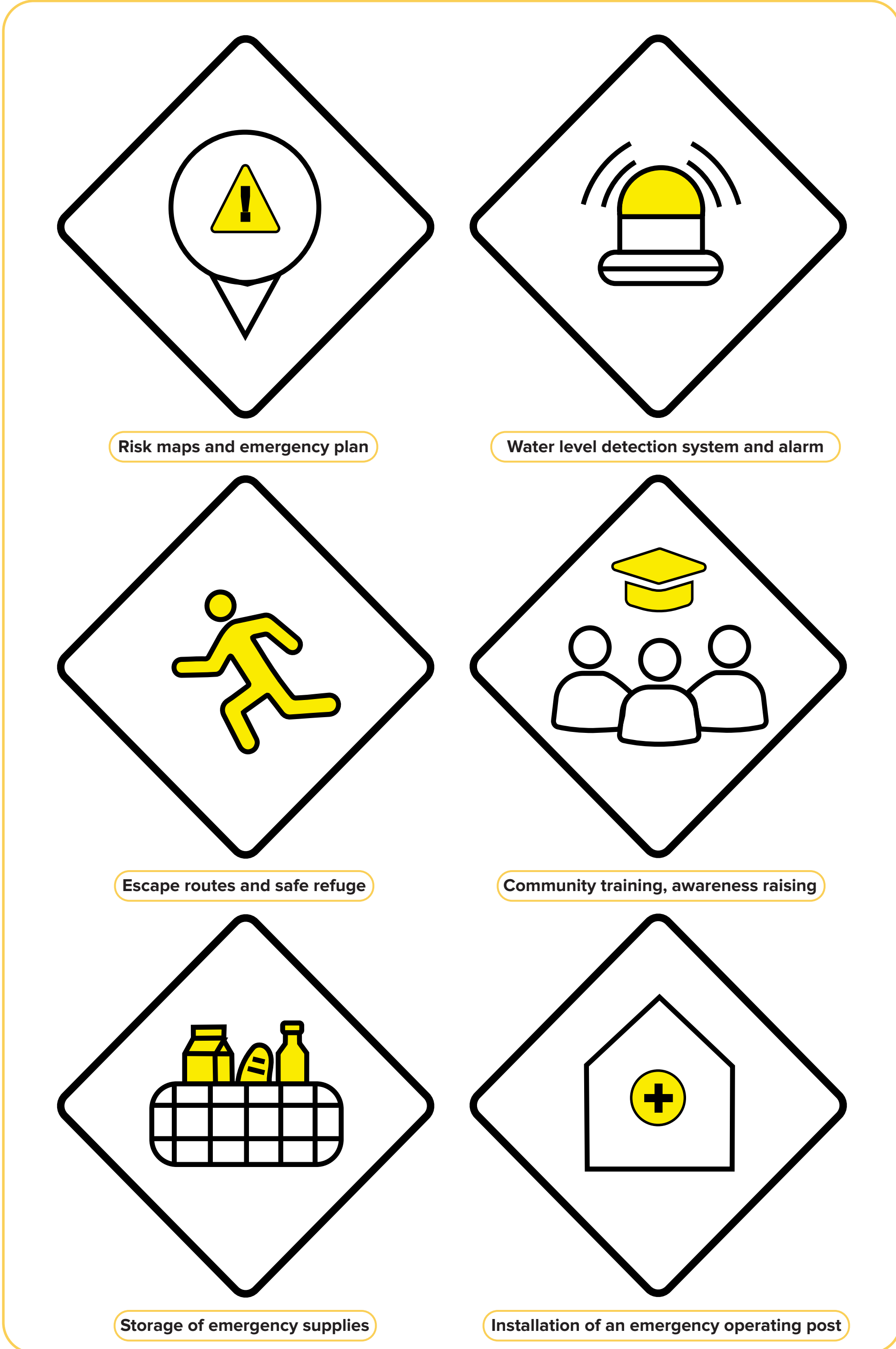
Intro

The preparedness phase combines the prevention of, the preparation for, and the individual precaution against hazards. Capacity building and raising risk awareness among the community strengthens the humanitarian settlements in their preparedness and responses to hazardous events. Preparedness measures include early warning systems, the planning of escape routes and refuge, the individual preparation of emergency bags, and the proper storage of emergency supplies and tools such as pumps or latrine pit emptying equipment. The stocks need to be controlled regularly to ensure materials are sufficient and functional.

Awareness raising campaigns need to convey simple key messages and be repeated regularly to ensure best comprehension of all members of the community. Community trainings on reacting to early warning systems, using escape routes and safe refuges are primordial to ensure the effectiveness of the preparedness measures. Inclusive and long-term capacity building can derive from educational efforts based on the combination of local, indigenous, and scientific knowledge systems. For this purpose, a dedicated disaster management cell or emergency operation center could be institutionalized within the humanitarian settlement, where selected people are trained on monitoring stocks, warning systems and other preparedness mechanisms. Local communities and humanitarian organizations can also prepare for disasters via land use plans, hazard maps, and (GIS-based) risk assessments (see *Measure [22] and GIS Add-In).*

Lesson learned

Early action against floods in the Bentiu camp, South sudan.
The Bentiu camp for internally displaced persons (IDP) in South Sudan was expected to face significant flooding during the 2022 rainy season. As a result, the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) and local partners initiated a pilot project for early floods risk mitigation. The initiative included a special task force and public project tracker to steer the preparations and decision-making. The process of early action was perceived a needed and effective measure by UN informants. However, early anticipatory action should leave more power in decision-making to the staff on site for accelerated risk mitigation processes. Moreover, the implemented mitigation should be continuously revised *(Evan Easton-Calabria, 2023).*



Overview of Criteria

Type of Intervention:
Non-structural.

Scale of Intervention:
Shelter-Plot-Block, Settlement

Materials:
NA.

Environmental Impact:
NA.

Targeted Natural Hazard:
Pluvial Flood, Coastal/Riverine Flood.

Targeted Vulnerable Assets:
Buildings, Transport, Technical Infrastructure.

Strategy Type:
Reduce Casualties.

Implementation Time:
Short (1 day - 1 month), Medium (1 month - 1 year), Long (> 1 year).

Effect Duration:
Short - term (<1 year), Medium - term (1 year to 10 years), Long - term (>10 years)

Investment Costs:
NA.

Maintenance Costs (yearly):
NA.

Calabria, Evan Easton; Jaime, Catalina; Shenouda, Benjamin (2022):
Anticipatory action in refugee and IDP camps: challenges, opportunities and considerations. ICRC.
Available online at
https://www.anticipation-hub.org/download/file-2568.

Calabria, Evan Easton (2023)
Acting in Advance of Flooding: Early action in South Sudan. Feinstein International Center.
Available online at
https://fic.tufts.edu/wp-content/uploads/05.10.23-ActingInAdvanceFinal.pdf.

IPCC: Climate Change (2022)
Impacts, Adaptation and Vulnerability. Summary for Policymakers. In : Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

22 | Participation

Environmental impact	3/3
Risk protection	3/3
Durability	3/3
Affordability	3/3

Intro

In the context of flood risk management, participation promotes the interaction among the stakeholders that are responsible for and affected by the implementation of the mitigation measures. Stakeholder engagement allows the (public, private, and local) stakeholders to come together for a dialogue on the interventions before and after their implementation.

Mapping the risk is one of the first steps to know what strategies would be best adapted to respond to a flood event. Hazard maps can be prepared using global and local data to draw a model of the probable extent of potential floods. Risk assessments will highlight the assets in need of protection and help prioritize mitigation actions. The process can involve participatory mapping. After identifying the essential stakeholders, the project initiator should actively listen and document the diverse perspectives. Then, the stakeholders' ideas and wishes should become part of the overarching goal and a common agenda for flood risk mitigation (and its monitoring) in the refugee camp.

The present project on risk mitigation strategies also includes guidelines for participatory mapping including semi-guided interview templates and a proposal for organization of mapping workshops.

Benefits and Risk

Participation permits the acknowledgment of different knowledge systems *(scientific, local, indigenous)* within a broader socio-political and cultural context *(Hofer and Kaufmann 2022; IPCC 2022b)*. Local knowledge can help tackle natural hazard risks in humanitarian settlements based on two categories. First, it can support the observation and prediction of changes in the natural environment. Second, laws valuing the natural environment such as non-building zones on riverbanks or the prohibition of logging can enhance the overall respectful approach to natural ecosystems while mitigating natural hazards *(Hiwasaki 2017)*.

Good practice

Raising community awareness in Myanmar.
The awareness of cyclone impacts has been raised within the community of the Irrawadi Delta in Myanmar. While building storm shelters for village communities in the delta, the Swiss Development Cooperation (SDC) integrated a strong participatory approach and disaster risk reduction (DRR) component into the process. The goal was to strengthen the population's resilience, capacity for self-reliance, and self-protection. To ensure a comprehensive and participatory approach, SDC prepared participatory workshops on community hazard mapping, mock drill training, role-playing exercises (simulations), tree-planting awareness sessions (including mangroves), and education on shelter/WASH maintenance.

Overview of Criteria

Type of Intervention:
Non-structural.

Scale of Intervention:
Shelter-Plot-Block, Settlement.

Materials:
NA.

Environmental Impact:
NA.

Targeted Natural Hazard:
Pluvial Flood, Coastal/Riverine Flood.

Targeted Vulnerable Assets:
Buildings, Transport.

Strategy Type:
Reduce Casualties.

Implementation Time:
Short (1 day - 1 month), Medium (1 month - 1 year).

Effect Duration:
Medium - term (1 year to 10 years).

Investment Costs:
Low.

Maintenance Costs (yearly):
NA.

Hiwasaki, Lisa: Local Knowledge for Disaster Risk Re Duction Including Climate Change Adaptation.
With assistance of Ilan Kelman, Jessica Mercer, J. C. Gaillard. In: The Routledge Handbook of Disaster Risk Reduction Including Climate Change Adaptation, pp. 227–237.

Hofer, Katrin; Kaufmann, David (2022)
Actors, arenas and aims:A conceptual framework for public participation. In Planning Theory, 147309522211395. DOI: 10.1177/14730952221139587.

PCC: Climate Change 2022
Impacts, Adaptation and Vulnerability. Summary for Policymakers. In : Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Pötz, Hiltrud (2016)
5 steps to stakeholder engagement and co-creation. Available online at https://www.urbangreenbluegrids.com/sponge/guide/,checked on 11/2/2022.Pötz 2016 (Hill Town)

List of figures

Publication bibliography

ACE Geosynthetics (2020): ACETube - Hydraulic structures. Geotextile Bags, Tubes and Containers. Available online at https://www.geoace.com/products/Geotextile-Bags%2C-Tubes-and-Containers/ACETube%C2%AE-_-hydraulic-structures.

ACE Geosynthetics (2020): ACETube Geotextile Tube Installation for Coastal Protection (Video). Available online at https://www.youtube.com/watch?v=s8yAtw4I-Ws.

ACE Geosynthetics (2020): Riverbank and Channel Protection. Levees and Dikes. Available online at https://www.geoace.com/app/Riverbank-and-Channel-Protection/Levees-and-Dikes.

ACE Geosynthetics (2020): Shoreline Protection, Ada Foah, Ghana. Available online at https://www.geoace.com/case/Marine-and-Coastal-Structures-Construction/Shoreline-Protection%2C-Ada-Foah%2C-Ghana.

Anthes, Emily: Amphibious Architecture. Float when it floods. In Anthropocene. Available online at https://www.anthropocenemagazine.org/2018/09/amphibious-architecture.

Bamboo House India (2017): Constructing a Bamboo House (Ground) – Process.

Calabria, Evan Easton (2023): Acting in Advance of Flooding: Early action in South Sudan. Feinstein International Center. Available online at https://fic.tufts.edu/wp-content/uploads/05.10.23-ActingInAdvanceFinal.pdf.

Calabria, Evan Easton; Jaime, Catalina; Shenouda, Benjamin (2022): Anticipatory action in refugee and IDP camps: challenges, opportunities and considerations. ICRC. Available online at https://www.anticipation-hub.org/download/file-2568.

Calow, Roger; Mason, Nathaniel; Tanjangco, Beatrice (2021): Nature-based solutionsfor flood mitigation. Available online at https://bracc.kulima.com/sites/default/files/2022-03/NBS%20for%20Flooding%20discussion%20paper.pdf.

Charlesworth, Susanne M.; Mctough, Mitchell; Adam-Bradford, Andrew (2021): The Design, Construction and Maintenance of a SuDS management Train to Address Surface water Flows by Engaging the Community: Gawilan Refugee Camp, Ninewah Governate, Kurdistan Region of Iraq. In Journal of Refugee Studies 34 (3), pp. 3494–3510. DOI: 10.1093/jrs/fez082.

Climate ADAPT (2022): Rehabilitation and restoration of rivers and floodplains. Available online at https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/rehabilitation-and-restoration-of-rivers, updated on 9/29/2023:34:14.

Climate ADAPT (2023): Dune construction and strengthening. Available online at https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/dune-construction-and-strengthening/#implementation.

Climate ADAPT (2023): Floating and amphibious housing. Available online at https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/floating-and-amphibious-housing/#success_factors.

Climate ADAPT (2023): Seawalls and jetties. Available online at https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/seawalls-and-jetties, updated on 9/29/2023:17:14.

Concept Concrete (2022): How Much Does Permeable Paving Cost? (Full Price Breakdown 2022) (Concept Concrete). Available online at https://conceptconcrete.com.au/blog/how-much-does-permeable-paving-cost/.

Connecting Nature (2020): ReDuna - Restoration of S. João da Caparica Sand Dunes. Available online at https://connectingnature.eu/oppla-case-study/22495, updated on 9/29/2023:29:33.

Dale's Marine Construction Inc. (2021): How to install riprap and have a good defining line between yard and riprap.

Design 1st. (2021): 5 New Flood Prevention Products. Available online at https://www.design1st.com/5-innovative-flood-prevention-products-replace-sandbags/.

Design Your Town (2022): Example of Roadside planter. Available online at http://www.designyourtown.org/design_detail/planter-boxes/.

Design Your Town (2022): Vegetated Swales. Available online at http://www.designyourtown.org/design_detail/vegetated-swales/.

elhra: SUSTAINABLE FLOOD RESILIENCE IN REFUGEE CAMPS: COMBINING SUSTAINABLE DRAINAGE WITH WASH. Available online at https://www.elrha.org/project/sustainable-flood-resilience-refugee-camps-combining-sustainable-drainage-wash/.

EM-DAT (2009): Classification of natural hazards by type of disaster. Available online at https://www.emdat.be/classification#Hydrological.

English, Elizabeth C. (2016): Amphibious Architecture. Where Flood Risk Reduction meets Climate Change Adaptation. Available online at https://www.munichre-foundation.org/content/dam/munichre/foundation/publications/2016_IMC_Day3_PS6%20Presentation%20English.pdf/_jcr_content/renditions/original./2016_IMC_Day3_PS6%20Presentation%20English.pdf.

Etat du Valais SRTCE (2015): 3rd Rhône's correction (State of Valais n.d.) in French only. Available online at http://www.vs.ch/documents/18863675/18936540/PA-R3.pdf/9eb5666f-39c6-4c6d-b7ce-eb5fd91c0f3b?t=1567774010746.

European Commission (2017): Humanitarian Shelter and Settlements Guidelines, DG ECHO Thematic Policy Document n° 9. Available online at https://ec.europa.eu/echo/files/policies/sectoral/shelter_and_settlement_guidelines.pdf.

European Commission (2021): Disaster Preparedness, DG ECHO Guidance Note. Available online at https://ec.europa.eu/echo/system/files/2022-02/dg_echo_guidance_note_-_disaster_preparedness_en.pdf.

FAG, Alcoforado (2018): Flood Control And Its Management. In Journal of Atmospheric & Earth Science 2 (1), pp. 1–13. DOI: 10.24966/AES-8780/100005.

FEMA (2021): Wet Floodproofing. Available online at https://www.fema.gov/glossary/wet-floodproofing, updated on 9/29/2023:01:09.

Fine Mesh Metals (2021): Gabion Standard Design. Available online at https://www.gabionbaskets.co.uk/gabion/gabion-wall-standard-design.

Flexamat (2022): Negative Impacts of Riprap on Lakeshores.

FloodWise (2023): Dry Floodproofing (Dry Floodproofing). Available online at https://floodwise.ca/protect-your-home-business/floodproofing/dry-floodproofing/.

Forestry Blog (2023): Different Types of Check Dams & Design Procedures. Available online at https://forestrybloq.com/different-types-of-check-dams/.

García, Miriam (2022): LEXICON FOR COASTAL RESILIENCE. Available online at https://lexiconforresilience.wixsite.com/my-site-2.

Geotech (2023): Gabion walls – function, application, advantage. Available online at https://www.geotech.hr/en/gabion-walls/.

Ghosh, S. N. (2018): Flood Control and Drainage Engineering. 4th ed.: CRC Press. Available online at https://www.routledge.com/Flood-Control-and-Drainage-Engineering/Ghosh/p/book/9781138077157#.

Global Shelter Cluster (2018): Shelter & Settlements. The Foundation of Humanitarian Response. Geneva.

Go Smart Bricks (2019): Top 7 Types Of Rainwater Harvesting Systems You Should Be Knowing (Go Smart Bricks). Available online at https://gosmartbricks.com/top-7-types-of-rainwater-harvesting-systems-you-should-be-knowing/.

GRAF Ireland Environmental Ltd (2023): How Do I Install A Rainwater Harvesting System? Available online at https://www.graf.info/en-ie/knowledge-hub/blog/how-do-i-install-a-rainwater-harvesting-system.html.

Green Roof Shelters Ltd (2022): The Green Roof Shelters Container family... In The Green Roof Shelters. Available online at https://greenroofshelters.co.uk/green-roof-shelters-container-family/.

Hapsari, Ratih Indri; Zenurianto, Mohammad (2016): View of Flood Disaster Management in Indonesia and the Key Solutions. In American Journal of Engineering Research 5 (3), pp. 140–151. Available online at https://d1wqtxts1xzle7.cloudfront.net/47615280/T050301400151-with-cover-page-v2.pdf?Expires=1649837882&Signature=ECic8PsAgRmMJWCKyTEWSIqs4o68~9zhk~I8IEC4MIlr7SHv3sWNmcDnkcmb2GPO1ZqGbqQyJlT-VhBsq7d8LUA~jGFurcPXGQDQLjA0kcQH4Vl29q6dJ0JNI2tq5wUTx5jOublZeozE6cmzofuTkpc~3C1RYO8TJoSQfE70NhUe~~iZTO2W9tixwpqLH-tzGVt4B~bHjN7~wLbzrt7cNpI~RwNTAR3uz5hNLYZF60Sc-nn8OCWeiyt0BqOkIR98f9RjmXlwTSOLcJljpMq5tJoXrZ4siR3VEfdQgf81A3uA-jVGmIXs-zlEZdYz-PsZJzQebem3nv433QwtDlppig__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA.

Heidari, A. (2014): Flood vulnerability of the Karun River System and short-term mitigation measures. In Journal of Flood Risk Management 7 (1), pp. 65–80. DOI: 10.1111/jfr3.12032.
Hiwasaki, Lisa: Local Knowledge for Disaster Risk Re Duction Including Climate Change Adaptation. With assistance of Ilan Kelman, Jessica Mercer, J. C. Gaillard. In : The Routledge

Handbook of Disaster Risk Reduction Including Climate Change Adaptation, pp. 227–237.
Hofer, Katrin; Kaufmann, David (2022): Actors, arenas and aims:A conceptual framework for public participation. In Planning Theory, 147309522211395. DOI: 10.1177/14730952221139587.

Hu, Pengbo; Ma, Yue; Xue, Huifeng; Zhang, Feng (2019): Application of low impact development technology in rainwater drainage system reconstruction project. In Cluster Computing 22 (1), pp. 533–543. DOI: 10.1007/s10586-017-1284-7.

IOM UN Migration (2020): Site Improvement Catalogue. Available online at https://www.humanitarianlibrary.org/resource/iscg-site-improvement-catalogue.

IOM Yemen (2022): Gabion Walls Protect Displaced People’s Life from Floods in Taiz.

IPCC: Climate Change 2022. Impacts, Adaptation and Vulnerability. Summary for Policymakers. In : Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC Intergovernmental Panel on Climate Change (2014): Glossary WGIIAR5-AnnexII. Available online at https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-AnnexII_FINAL.pdf.

Jerome Glago, Frank (2021): Flood Disaster Hazards; Causes, Impacts and Management: A State-of-the-Art Review. In : Natural Hazards - Impacts, Adjustments and Resilience: IntechOpen.

John, Regina (2020): Flooding in Informal Settlements: Potentials and Limits for Household Adaptation in Dar es Salaam City, Tanzania. In American Journal of Climate Change 09 (02), pp. 68–86. DOI: 10.4236/ajcc.2020.92006.
Kreibich, Heidi; Bubeck, Philip; van Vliet, Mathijs; Moel, Hans de (2015): A review of damage-reducing measures to manage fluvial flood risks in a changing climate. In Mitigation and Adaptation Strategies for Global Change 20 (6), pp. 967–989. DOI: 10.1007/s11027-014-9629-5.

Leung, Tak (2014): Amphibious Bamboo House. Available online at https://issuu.com/tak.leung/docs/amphibious_bamboo_house_issuu, updated on 9/29/2023:37:39.

Loyce, Nabie (2021): Construction of Dike Brings Hope to Flood-Affected Communities in Bor. IOM South Sudan. Available online at https://southsudan.iom.int/stories/construction-dike-brings-hope-flood-affected-communities-bor, updated on 9/29/2023:55:10.

Lymath, Anthony (2014): Flood mitigation solutions in buildings - Part One, Two, Three. Available online at https://www.thenbs.com/knowledge/flood-mitigation-solutions-in-buildings.

Mabuku, Monde Patrina; Senzanje, Aidan; Mudhara, Maxwell; Jewitt, Graham; Mulwafu, Wapulumuka (2018): Rural households’ flood preparedness and social determinants in Mwandi district of Zambia and Eastern Zambezi Region of Namibia. In International Journal of Disaster Risk Reduction 28, pp. 284–297. DOI: 10.1016/j.ijdrr.2018.03.014.

Martinez, Maria; Bakheet, Ramez; Akib, Shatirah (2021): Innovative Techniques in the Context of Actions for Flood Risk Management: A Review. In Eng 2 (1), pp. 1–11. DOI: 10.3390/eng2010001.

Massachusetts Clean Water Toolkit (2023:04:51): Riprap. Available online at https://megamanual.geosyntec.com/npsmanual/riprap.aspx, updated on 9/29/2023:04:51.

Mediterranean membership network of wetland managers (2021): A success story: restoration of the Azraq Wetland, Jordan. Available online at https://medwetmanagers.net/a-success-story-restoration-of-the-azraq-wetland-jordan/.

Minnesota Stormwater Manual (2022): Design criteria for permeable pavement. Available online at https://stormwater.pca.state.mn.us/index.php/Design_criteria_for_permeable_pavement, updated on 9/29/2023:32:55.

Moccia, F. D.; Sgobbo, A. (2013): Flood hazard: planning approach to risk mitigation. Available online at https://www.witpress.com/Secure/elibrary/papers/SAFE13/SAFE13009FU1.pdf.

Mseleku, Erasmus (2021): Guidelines for Integrated Flood Control Design in the Informal Settlements of Cape Town Municipality. A case study of Kosovo, Philippi District.

Muhatiah, Wentland Ngalushi (2021): Enhancing adaptive capacity of communities in informal settlements to flooding: The case of Mukuru Kwa Reuben in Nairobi, Kenya. Available online at http://erepository.uonbi.ac.ke/bitstream/handle/11295/156014/Muhatiah_Enhancing%20adaptive%20capacity%20of%20communities%20in%20informal%20settlement%20to%20flooding.pdf?sequence=3&isAllowed=y.

National Association of City Transportation Officials: Urban Street Stormwater Guide. Available online at https://nacto.org/publication/urban-street-design-guide/.
Naturally Resilient Communities: USING NATURE TO ADDRESS FLOODING. Available online at http://nrcsolutions.org/.

Nguyen, Cong Dinh; Ubukata, Fumikazu; Nguyen, Quang Tan; Vo, Hoang Ha (2021): Long-Term Improvement in Precautions for Flood Risk Mitigation: A Case Study in the Low-Lying Area of Central Vietnam. In Int J Disaster Risk Sci 12 (2), pp. 250–266. DOI: 10.1007/s13753-020-00326-2.

Nova Scotia: Wetland Compensation - What's Required and What Are My Options? Available online at https://novascotia.ca/nse/wetland/docs/Wetland_Compensation.pdf.

NWRM, Natural Water Retention Measures (2015): Floodplain restoration and management. Available online at http://nwrm.eu/measure/floodplain-restoration-and-management, updated on 9/29/2023:30:19.

Padoan, Laura (2018): Seeds of hope: Chelsea Flower Show inspires refugee gardeners Lemon Tree Trust's garden reflects the hidden beauty in refugee camps. In UNHCR USA. Available online at https://www.unhcr.org/news/latest/2018/5/5b05755b4/seeds-of-hope-chelsea-flower-show-inspires-refugee-gardeners.html.

Paolinelli, Gabriele; Cei, Marco; Cristiani, Nicoletta; Marinaro, Ludovica; Veronesi, Flavia (2022): Don't Split Them Up! Landscape Design of Multifunctional Open Spaces Suitable for Coping with Flash Floods and River Floods. In Sustainability 14 (4). DOI: 10.3390/su14042316.

Pavement Materials Group (2023): Terracrete Grass Block Paver (350 x 350 x 100). Available online at https://www.pavementmaterials.co.za/products/terracrete-grass-block-paver-suplier-south-africa, updated on 9/29/2023:28:05.

PEDRR (2020): Glossary. Selected Ecosystem-Based Disaster and Climate Change Terminology. Available online at https://pedrr.org/glossary/.

Phadtare, Imelda (2020): Disaster Risk Reduction and mitigation: green growth in Jordan's humanitarian sector. Available online at https://www.ecoltdgroup.com/disaster-risk-reduction-and-mitigation-green-growth-in-jordans-humanitarian-sector/.

Pötz, Hiltrud (2016): 5 steps to stakeholder engagement and co-creation. Available online at https://www.urbangreenbluegrids.com/sponge/guide/, checked on 11/2/2022.

Prabnakorn, Saowanit (2020): Integrated flood and drought mitigation measures and stategies : Case study: The Mun River Basin, Thailand. DOI: 10.18174/501426.

Ramsar (2019): Wetlands: The key to coping with climate change. Available online at https://www.ramsar.org/sites/default/files/documents/library/wwd19_handout_e.pdf.

REACH (2021): Flooding Susceptibility and Preparedness Survey (FSPS) SYR2101 Syria. Available online at https://reliefweb.int/sites/reliefweb.int/files/resources/REACH_SYR_Flooding-Susceptibility-and-Preparedness-Survey_public.pdf.

Ruangpan, L.; Vojinovic, Z.; Di Sabatino, S.; Leo, L. S.; Capobianco, V.; Oen, A. M. P. et al. (2020): Nature-based solutions for hydro-meteorological risk reduction: a state-of-the-art review of the research area. In Natural Hazards and Earth System Sciences 20 (1), pp. 243–270. DOI: 10.5194/nhess-20-243-2020.

Sambito, Mariacrocetta; Severino, Alessandro; Freni, Gabriele; Neduzha, Larysa (2021): A Systematic Review of the Hydrological, Environmental and Durability Performance of Permeable Pavement Systems. In Sustainability 13 (8), p. 4509. DOI: 10.3390/su13084509.
Satterthwaite, David; Archer, Diane; Colenbrander, Sarah; Dodman, David; Hardoy, Jorgelina; Mitlin,

Diana; Patel, Sheela (2020): Building Resilience to Climate Change in Informal Settlements. In One Earth 2 (2), pp. 143–156. DOI: 10.1016/j.oneear.2020.02.002.

Scnat Netzwerk (2023:31:33): Floodplains: a natural system to preserve and restore (EEA Report, 24/2019). Available online at https://scnat.ch/de/uuid/i/96de4fa4-ee4a-5f7e-9f07-ca302becfabf-Floodplains_a_natural_system_to_preserve_and_restore.

Seif-Ennasr, Marieme; Zaaboul, Rashyd; Hirich, Abdelaziz; Caroletti, Giulio Nils; Bouchaou, Lhoussaine; El Morjani, Zine El Abidine et al. (2016): Climate change and adaptive water management measures in Chtouka Aït Baha region (Morocco). In Science of The Total Environment 573, pp. 862–875. DOI: 10.1016/j.scitotenv.2016.08.170.

Serlet, Murielle (2020): Study on shelter response of Caritas Bangladesh for the Forcibly-Displaced Citizens of Myanmar. 2018. Available online at https://craterre.hypotheses.org/2498, updated on 2020.

Sivakumar, Saravanamuttu (2015): Flood Mitigation Strategies Adopted in Sri Lanka A Review. In International Journal of Scientific and Engineering Research 6.

Sphere (2018): The Sphere Handbook. Fourth edition. Geneva Switzerland: Sphere Association.

Sphere Association (2018): The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response. 4th ed. Geneva, Switzerland. Available online at www.spherestandards.org/handbook.

SUGi (2022): Revive waterways and biodiversity in Cameroon. Available online at https://www.sugiproject.com/projects/bulu, updated on 9/29/2023:07:54.

susDrain (2022): SuDS management train. Available online at https://www.susdrain.org/delivering-suds/using-suds/suds-principles/management-train.html.

susDrain (2022): Sustainable Drainage. Available online at https://www.susdrain.org/delivering-suds/using-suds/background/sustainable-drainage.html.

Suttles, Kelly M.; Eagle, Alison J.; McLellan, Eileen L. (2021): Upstream Solutions to Downstream Problems: Investing in Rural Natural Infrastructure for Water Quality Improvement and Flood Risk Mitigation. In Water 13 (24). DOI: 10.3390/w13243579.

Tanwattana, Puntita (2018): Systematizing Community-Based Disaster Risk Management (CBDRM): Case of urban flood-prone community in Thailand upstream area. In International Journal of Disaster Risk Reduction 28, pp. 798–812. DOI: 10.1016/j.ijdrr.2018.02.010.

Tarchiani, Vieri; Massazza, Giovanni; Rosso, Maurizio; Tiepolo, Maurizio; Pezzoli, Alessandro; Housseini Ibrahim, Mohamed et al. (2020): Community and Impact Based Early Warning System for Flood Risk Preparedness: The Experience of the Sirba River in Niger. In Sustainability 12 (5). DOI: 10.3390/su12051802.

Tariq, Muhammad Atiq Ur Rehman; Farooq, Rashid; van de Giesen, Nick (2020): A Critical Review of Flood Risk Management and the Selection of Suitable Measures. In Applied Sciences 10 (23). DOI: 10.3390/app10238752.

Tasawwar, Sumbal; Kassaye, Rahel Birhanu; Schaldach, Ruth (2018): Traditional Ecological Knowledge (TEK): Rainwater Harvesting Methods – A Review. Available online at https://www.ruvival.de/wp-content/uploads/2018/07/Traditional_Ecological_Knowledge_Rainwater_Harvesting_Working_Paper.pdf.

The Associated Programme on Flood Management (2012): FLOOD PROOFING. INTEGRATED FLOOD MANAGEMENT TOOLS SERIES. Available online at https://www.floodmanagement.info/publications/tools/APFM_Tool_15.pdf.

The Associated Programme on Flood Management (2017): COMMUNITY-BASED FLOOD MANAGEMENT. Integrated flood management tools series. Available online at https://reliefweb.int/sites/reliefweb.int/files/resources/APFM_Tool_4_e.pdf.

The Conservation Volunteers: How to manage sand dunes. Available online at https://conservationhandbooks.com/manage-sand-dunes/.

The National Academies of Sciences, Engineering, and Medicine (2019): Riprap Design Criteria, Recommended Specifications, and Quality Control. Available online at https://www.trb.org/Main/Blurbs/155703.aspx.

The United States Society on Dams (2022): Glossary. Available online at https://www.ussdams.org/resource-center/glossary/.

Tucker, Emma (2016): TetraPOT is a greener alternative to concrete coastal defences. In dezeen. Available online at https://www.dezeen.com/2016/10/24/tetrapot-coastal-defence-design-plant-pot-sheng-hung-lee-china/.

UKCEH; UK Sand Dune and Shingle Network and Dynamic Dunescapes partners (2021): The Sand Dune Managers Handbook. 1st ed.: Produced for the Dynamic Dunescapes (DuneLIFE) project: LIFE17 NAT/UK/000570; HG-16-08643. Available online at https://dynamicdunescapes.co.uk/wp-content/uploads/2021/07/Dynamic-Dunescapes-Sand-Dune-Managers-Handbook-June-2021.pdf.

Ullal, André; Estrella, Xavier (2021): South Sudan - State-of-the-Art on Flood Resilient Shelters.

UN Environment Programme (2020): Celebrating International Mangrove Day: spare a thought for our coastal ecosystems. Available online at https://www.unep.org/news-and-stories/story/celebrating-international-mangrove-day-spare-thought-our-coastal-ecosystems.

UN Environment Programme (2020): How climate change is making record-breaking floods the new normal. Available online at https://www.unep.org/news-and-stories/story/how-climate-change-making-record-breaking-floods-new-normal.

UNDRR (2020): HAZARD DEFINITION AND CLASSIFICATION REVIEW. Available online at https://www.undrr.org/publication/hazard-definition-and-classification-review.

UNDRR (2020): Mitigation. Available online at https://www.undrr.org/terminology/mitigation.

UNDRR Asia-Pacific (2020): Ecosystem-Based Disaster Risk Reduction: Implementing Nature-based Solutions for Resilience. Available online at https://www.undrr.org/publication/ecosystem-based-disaster-risk-reduction-implementing-nature-based-solutions-0.

UNEP-Nairobi Convention; USAID; WIOMSA (2020): Guidelines on Mangrove Ecosystem Restoration for the Western Indian Ocean Region. Available online at https://www.nairobiconvention.org/CHM%20Documents/WIOSAP/guidelines/GuidelinesonMangroveRestorationForTheWIO.pdf.

UN-Habitat Myanmar (2015): Manual on Flood - Causes, Effects & Preparedness. Available online at https://themimu.info/sites/themimu.info/files/documents/Guideline_Flood%20Manual_UN-Habitat.pdf.

UNHCR: The Master Plan Approach To Settlment Planning. Guiding Principles.

UNHCR (2022): UNHCR Mid-Year Trends 2022. Available online at https://reliefweb.int/report/world/unhcr-mid-year-trends-2022, updated on 9/29/2023:50:36.

UNISDR (2017): Words into Action Guidelines: National Disaster Risk Assessment Hazard Specific Risk Assessment. Available online at https://www.unisdr.org/files/52828_04floodhazardandriskassessment.pdf.

Universiti Malaysia Sarawak (2019): Green walls could buffer flash flooding in cities. Available online at https://phys.org/news/2019-01-green-walls-buffer-cities.html.

van Wesenbeeck, Bregje K.; IJff, Stéphanie; Jongman, Brenden; Balog, Simone; Kaupa, Stefanie; Bosche, Lauren et al. (2017): Implementing naturebased flood protection Principles and implementation guidance. Available online at https://www.gfdrr.org/sites/default/files/publication/Brochure%20Implementing%20nature-based%20flood%20protection_voor%20web.pdf.

Ward, Philip J.; Ruiter, Marleen C. de; Mård, Johanna; Schröter, Kai; van Loon, Anne; Veldkamp, Ted et al. (2020): The need to integrate flood and drought disaster risk reduction strategies. In Water Security 11, p. 100070. DOI: 10.1016/j.wasec.2020.100070.

Watkins, Simon (2017): Sustainable Flood Resilience in Refugee Camps; Combining sustainable drainage (SuDS) with WASH.

Watson, Donald; Adams, Michele (2010): Design for Flooding: Architecture, Landscape, and Urban Design for Resilience to Climate Change: John Wiley & Sons Inc. Available online at https://www.wiley.com/en-us/Design+for+Flooding%3A+Architecture%2C+Landscape%2C+and+Urban+Design+for+Resilience+to+Climate+Change-p-9780470475645#download-product-flyer.
Watson, Julia (2020): Lo–TEK. Design by Radical Indigenism.