Convention on the Protection and Use of Transboundary Watercourses and International Lakes

Second Joint meeting of the Working Groups on Monitoring and Assessment and on Integrated Water Resources Management

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Adapting to climate change in transboundary basins

DRAFT Words into Action

Implementation Guide for Addressing Water-Related Disasters and Transboundary Cooperation

Integrating disaster risk management with water management and climate change adaptation

Summary and proposed action by the Task Force on Water and Climate

The Sendai Framework for Disaster Risk Reduction 2015–2030 was adopted at the Third United Nations World Conference on Disaster Risk Reduction (WCDRR) in Sendai, Japan, in March 2015 and was subsequently endorsed by the United Nations General Assembly. In order to support the process, a number of targeted Sendai Framework implementation guides are being developed to generate practical and evidence-based guidance for its implementation in close collaboration with States and through the mobilization of experts, thus reinforcing a culture of prevention among relevant stakeholders.

The majority of disasters are water-related. In addition, around 60% of all freshwater flow worldwide occurs in transboundary basins. Under the aegis of the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention), the Task Force on Water and Climate has worked on promoting transboundary cooperation in climate change adaptation and disaster risk reduction since its creation in 2006 by contributing to global processes on climate and disasters.

As suggested by the United Nations Office for Disaster Risk Reduction (UNISDR) at the seventh session of the Meeting of the Parties to the Water Convention (Budapest, Hungary, 17–19 November 2015), the Working Group on Integrated Water Resources Management at its eleventh meeting (Geneva, 18 to 19 October 2016) decided to develop an implementation guide on "Addressing Water-Related Disasters and Transboundary Cooperation" and entrusted the Task Force on Water and Climate to prepare a draft in cooperation with UNISDR. In 2017, the present draft guide was developed by a drafting group under the leadership of the Netherlands. It was subsequently reviewed and discussed by the Task Force on Water and Climate at its ninth meeting (Geneva, 13 December 2017) and was peer-reviewed and edited.

* Second joint meeting of the two working groups.

The Working Group on Integrated Water Resources Management and the Working Group on Monitoring and Assessment are invited at their joint meeting to review and comment on the draft guide and entrust the drafting group to address the comments received so as to prepare a final version of the guide for endorsement at the eighth session of the Meeting of the Parties to the Water Convention (Astana, Kazakhstan, 10–12 October 2018).

As this guide is a joint document with UNISDR, it will also at the same time undergo a number of steps in the quality control process, as foreseen for Words into Action guides, namely a peer review by UNISDR and an open online consultation.

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Editorial group

- Jos Timmerman, Wageningen Environmental Research (Alterra), The Netherlands (lead author)
- Alexander Belokurov, Water Convention, Environment Division, United Nations Economic Commission for Europe
- Sonja Koeppel, Water Convention, Environment Division, United Nations Economic Commission for Europe
- Alisher Mamadzhanov, Water Convention, Environment Division, United Nations Economic Commission for Europe
- Giacomo Terruggi, World Meteorological Organisation

Drafting group:

- Alfredo Mamani Salinas, previously Autoridad Binacional del Lago Titicaca, Peru
- Malik Fida A Khan, Center for Environmental and Geographic Information Services, Bangladesh
- Nguyen Huong Thuy Phan, Independent Expert, Water and Climate Change, previously Mekong River Commission
- Anne Chaponniere, Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)
- Glenn Dolcemascolo, United Nations Office for Disaster Risk Reduction
- Maria del Mar Oliva Rodriguez, World Meteorological Organisation
- Robert Slomp, Rijkswaterstaat, Ministry of Infrastructure and the Environment, The Netherlands
- Susanna Tol, Wetlands International
- Frank van Weert, Wetlands International
- Armen Rostomyan, Independent expert on Disaster Risk Reduction
- Marco Toscano-Rivalta, United Nations Office for Disaster Risk Reduction
- Dave Zervaas, United Nations Office for Disaster Risk Reduction

Reviewers

- Anita van Breda, World Wildlife Fund, USA
- John Matthews, The Alliance for Global Water Adaptation
- Mihail Kochubovski, Institute of Public Health, The Former Yugoslav Republic of Macedonia
- Callist Tindimugaya, Ministry of Water and Environment, Uganda
- Nanco Dolman, Royal Haskoning DHV, The Netherlands
- Fadi Hamdan, Disaster Risk Management Center, Lebanon
- Max, Linsen`, Directorate General for Environment, European Commission
- Adrian Schmid-Breton, International Commission for the Protection of the Danube River
- Roman Corobov, Independent expert, Republic of Moldova
- Raimund Mair, Directorate General for Environment, European Commission

Comments and other contributions

- Ebru A. Gencer, Center for Urban Disaster Risk Reduction Resilience
- Katharine Cross, International Water Association
- Franziska Hirsch, Convention on the Transboundary Effects of Industrial Accidents, Environment Division, UNECE
- Tea Aulavuo, Espoo Convention, Environment Division, UNECE
- Ruth Richardson, Boardmember International Network of Liberal Women
- Kawa Sahab, Ministry of Energy & Water, Islamic Republic of Afghanistan

Designer

- Valerio Lo Bello

Editor

- Cathy Lee

List of abbreviations and acronyms

CBA	Cost-benefit analysis
CCA	Climate change adaptation
COP	Conference of the Parties
DRA	Disaster Risk Assessment
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EIA	Environmental Impact Assessment
EU	European Union
FD	Floods Directive
FRMP	Flood Risk Management Plan
ICPDR	International Commission for the Protection of the Danube River
ICPR	International Commission for the Protection of the Rhine
IGO	Intergovernmental organization
INBO	International Network of Basin Organizations
IRBD	International River Basin District
IWRM	Integrated Water Resources Management
GIS	Geographic Information System
GWP	Global Water Partnership
MCA	Multi-criteria analysis
NGO	Non-governmental organization
OECD	Organisation for Economic Co-operation and Development
PEDRR	Partnership for Environment and Disaster Risk Reduction
SDGs	Sustainable Development Goals
SEA	Strategic Environmental Assessment
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations Office for Disaster Risk Reduction
WCDRR	United Nations World Conference on Disaster Risk Reduction
WMO	World Meteorological Organization

DRAFT Words into Action

Implementation Guide for Addressing Water-Related Disasters and Transboundary Cooperation

Table of contents

1. Key messages

Water is central to a vast array of sectors that directly depend on the availability of high quality water resources. Consequently, water management can limit or enhance the risk of disaster in these water-related sectors. The impacts of climate change on water are expected to have cascading effects on human health and well-being, as well as many sectors of the economy, which would invariably lead to increased disaster risks.

Transboundary cooperation is both necessary and beneficial throughout the entire process of developing and implementing a joint strategy of disaster risk management. International basins make up about half of the Earth's land surface, and the fact that many water bodies straddle boundaries means that risks and challenges are shared such that solutions need to be coordinated. Moreover, the coordination of water management can unlock benefits that cannot be achieved through unilateral development. With this in mind, the Sendai Framework stresses the importance of transboundary cooperation.

An integrated approach towards water management, as laid down in the concept of Integrated Water Resources Management (IWRM) that entails a comprehensive, coordinated and systematic process of planning, control, organization, leadership and management within a basin is imperative for reducing disaster risks and for developing and implementing a disaster risk management strategy. General activities under IWRM of special importance in transboundary basins include: i) maintaining a water balance for the entire basin; ii) good communication between riparian countries; iii) jointly defining issues and arriving at a common understanding of interests among all riparian countries; iv) sharing hydro-meteorological data across borders, as well as a joint legal and institutional framework for cooperation, pilot projects and regional and sub-regional workshops on transboundary water management; and v) capacity-building and training at both the technical and decision-making levels, and on early warning.

Joint bodies and/or regional organizations are important mechanisms for the coordination of planning and the implementation of disaster risk reduction measures. Such mechanisms should be founded in international and bi- or multilateral agreements.

Disaster risk management measures need to be flexible. This is required by the uncertainties that exist as regards the direction and nature of the changes in hydrological systems caused by climate change. The interventions chosen should be flexible enough to deliver maximum benefits under a range of conditions instead of being designed for the 'most likely' future conditions. In this way, should conditions change or prove different from those expected today, the measures taken should be capable of responding to this change.

Ensuring that data and information are readily available is crucial for climate projections and for identifying vulnerable groups and regions and disaster risks. Sharing information, including from early warning systems between countries and sectors, is therefore essential for the effective and efficient management of disaster risk. Moreover, early warning systems are important measures in mitigating the impacts of extreme events.

Uncertainty should never be a reason for inaction. Although what we know about climate change is qualified by a level of uncertainty, we can still identify trends that allow us to act. A twin-track approach, combining immediate action and further research, is therefore recommended. Water management and water-related policies and measures need to be adapted to climate change now on the basis of what we know already. Nevertheless, more needs to be done in terms of research into the impacts of climate change so as to further our knowledge.

Disaster risk management requires coordination across all governance levels from local to international. Where the number of governance levels are higher, as in federal states, the need for coordination over administrative borders only increases.

Effective disaster risk management requires a cross-sectoral approach that includes the transboundary level in order to prevent possible conflicts between the different sectors, and to consider trade-offs and synergies between the various measures. Uncoordinated sectoral responses can be ineffective or even counterproductive because a response in one sector can increase the vulnerability of another sector and/or reduce the effectiveness of their disaster risk responses.

It is increasingly acknowledged that degrading ecosystems such as wetlands further complicate the context of disaster risk. Degraded systems are often a contributing factor to the development of hazards while at the same time people derive less goods and services from such systems, reducing their overall resilience. Such ecological effects can ripple through water related systems and may even cross borders. Hence, the implementation of the Sendai Framework within a transboundary context should include ecosystem management and restoration, and the use of ecosystems as green infrastructure to mitigate the impacts of disaster risk.

Riparian countries should focus on generating basin-wide benefits and on sharing those benefits in a fair and agreed manner. Focusing on sharing the benefits derived from the use of water, rather than the allocation of water itself, would provide far greater scope in identifying mutually beneficial and cooperative actions, and thus serve as a good basis for developing and implementing a disaster risk management strategy.

The implementation of national legislation and international commitments can support disaster risk management. A number of international agreements include provisions and tools that can support the development of disaster risk strategies. Countries should take this into account and build on such provisions to maximize results while ensuring the coherence of their adopted policies and measures.

2. Introduction

2.1 Context and rationale

A large part of disaster risk is directly or indirectly linked to water (e.g. flood, drought, typhoons/ cyclones, flashfloods, landslides, water quality emergencies). Floods, droughts and storms affected 4.2 billion people (95 per cent of all people affected by disasters) and caused US$1.3 trillion of economic losses since 1992 (WCDRR, 2014). The number of people affected and the estimated damage from water-related disasters continue to increase. This increase can be partially explained by better reporting and the documentation of these disasters and its consequences such as through the Emergency Events Database (EM-DAT[1]). However, the main explanation lies in the fact that the occurrence and magnitude of natural hazards[2] like floods and droughts have increased due to higher weather variability as a result of climate change, as well as to changing land and water practices and land use. The number of people affected by flood hazards and droughts has increased and will continue to do so as the population grows and as people move to marginal lands known to be exposed to such hazards, especially in developing countries, which is exacerbated by poverty, land shortages, urbanization and the poor condition of flood protection and drainage infrastructure. Moreover, droughts (as slowly developing disasters) may lead to the collapse of social structures and to refugee crises that cause disruptions in the social structures of adjacent regions.

Fortunately, the higher number of people affected by disasters is not accompanied by casualties. The reduction in fatalities probably has to do with the fact that timely warnings are given and are increasingly also heeded (Lumbroso *et al.*, 2017). This suggests that some areas of disaster risk management are working. To conclude, disaster impact statistics show a global trend in which more disasters occur, greater populations are affected but fewer people die, and economic losses are increasing (IFRC, 2000). The negative impacts of disasters exacerbate inequalities and are disproportionately borne by poor and vulnerable communities. Developing robust solutions to manage the escalating disaster risks due to rapid global changes will call for new strategies and a stronger capacity to absorb expected changes (WCDRR, 2014).

The 276 transboundary lake and river basins worldwide cover nearly one half of the Earth's land surface and account for an estimated 60 per cent of global freshwater flow. A total of 145 States include territory within such basins, and 30 countries lie entirely within them. In addition, about 2 billion people worldwide depend on groundwater, which includes approximately 300 transboundary aquifer systems (UNEP, 2012). The risks and challenges connected to these waters are shared between the neighbouring countries, and transboundary cooperation is essential as transboundary basins are often more vulnerable to disasters (Bakker, 2006; 2009). Consequently, solutions need to be coordinated. Countries within a region face similar disaster risks as they share the regional driver, for example, a 'simultaneous' increase in floods in various European countries can result from a high intensity of regional-level precipitation (e.g. Blöschl *et al.*, 2017). Similarly, the frequency and intensity of drought can increase across several countries in Africa because of regionally reduced precipitation. Additionally, hazards or causes for hazards can spread through a river basin connecting upstream and downstream countries and thus expand the context of disaster risk management. Furthermore, unilateral adaptation and disaster risk reduction measures can have negative impacts on other riparian countries. Cooperating on adaptation strategies can help riparian countries find better and more cost-effective solutions by considering a larger geographical area in planning measures, by broadening the information base,

[1] More information available from http://emdat.be
[2] For a discussion on natural and human-induced hazards and disasters, please refer to Kelman *et al.*, 2016. Also see the glossary in this report.

by exchanging data, and by combining efforts and pooling resources (Leb *et al.* 2018). This guide therefore seeks to place disaster risk reduction (DRR) in water management within the context of transboundary cooperation.

Integrated Water Resources Management (IWRM) at the basin level is extremely important in reducing the growing disaster risk, while taking into account climate change. IWRM can help reduce the disaster risks caused by flooding and droughts. For instance, measures and infrastructure to retain surplus water can help reduce flooding from heavy precipitation or droughts when stored for dry periods. Already over 50 per cent of all renewable and 'accessible' freshwater flows is attributed to human use, including in-stream dilution of human and industrial wastes (Postel *et al.*, 1996), and thus water demand management is an important means to lessen the impacts of drought. Moreover, ecosystems play a pivotal role in both flood and drought risk reduction and should therefore have an important role in water management. Disaster risk can be reduced significantly through appropriate water management, including having effective measures involving the right stakeholders, and addressing the risks at appropriate scales. In addition, the role of appropriate communication at the various scales and to all stakeholders (for example, in early warning systems enabling early action) cannot be underestimated. The most effective and efficient scale for risk reduction with regard to most water-related disasters is at the basin level where the necessary understanding is built and measures are developed. In order to achieve the targets of the Sendai Framework priority should be given to the proper consideration of measures to address water-related disasters and associated transboundary cooperation.

There are, however, obstacles that inhibit the consideration of transboundary cooperation. Among the many reasons cited are the fear of losing national sovereignty, misperceptions about the cost and benefits of transboundary cooperation, and lack of political will. In many situations, technical cooperation comes before institutional and political cooperation. It is often easier to start cooperation and address the problems at the technical and expert levels, thereby building trust. But even when countries are ready to promote transboundary cooperation, they may still have insufficient capacity to assess transboundary disaster risks and to develop and implement transboundary disaster risk management plans. Subsequent to this, the siloed sectoral approach to the planning, development and management of water and related resources at the national level hinders transboundary cooperation.

2.2 Aims and scope

This Words into Action Guide has been prepared to support the implementation of the Sendai Framework. It aims to raise awareness on the importance of river basin management and transboundary cooperation in DRR, while taking into account climate change adaptation. It provides information on steps that governments in particular at the different levels can take to harness the values of river basin management and transboundary cooperation together with good practices and lessons learned in this field. Disaster Risk Management (DRM) in this guide is considered as the implementation of DRR. DRM describes and implements actions that aim to achieve the objectives of reducing risk.

The general objective of this guide is to support the implementation of the Sendai Framework in (transboundary) basins through bringing together disaster risk management, integrated water management and climate adaptation approaches. This includes ensuring that IWRM issues are considered at all levels including the international level, and that the role of water and basins is taken into account. The guide will also consider the framework of various international commitments including the Paris Agreement and the Sustainable Development Goals (SDGs). Taken together, while ultimately measures are taken at the local level, policy development and planning should take into account transboundary aspects when relevant. Consequently, a national disaster risk management strategy cannot be developed without first looking at relevant transboundary aspects and vice versa. Moreover, even at the national level, administrative boundaries exist (e.g. states, provinces, counties, and so on). Thus, the transboundary approach applies to all governance levels, and the approaches and methodologies described in this guide are relevant at all levels.

The purpose of this guide is not to offer a detailed methodology that could be followed step by step, but rather to propose a set of principles and guidance with references to additional materials that combine disaster risk approaches with transboundary water management and climate adaptation. This guide is intended to offer guidance to countries implementing the Sendai Framework as well as help in implementing the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) with regards to disasters and climate change. This guide is not legally binding and does not preclude the legal obligations arising from the Convention.

2.3 Target audience

The main target groups for this guide are practitioners in DRR and water management, more specifically, water managers, institutions and authorities responsible for DRR at local, regional, national and international levels, including joint bodies, like river basin commissions. The guide is also relevant for non-governmental organizations (NGOs) and intergovernmental organizations (IGOs) that deal with water-related issues. As water management cannot be separated from water users and often water users' behaviour and decisions result in human-induced hazards, the guide will also be relevant for—but not specifically—water users such as the industry, agriculture and energy sectors, among others. Furthermore, the guide could also be useful for the sector of humanitarian and development aid.

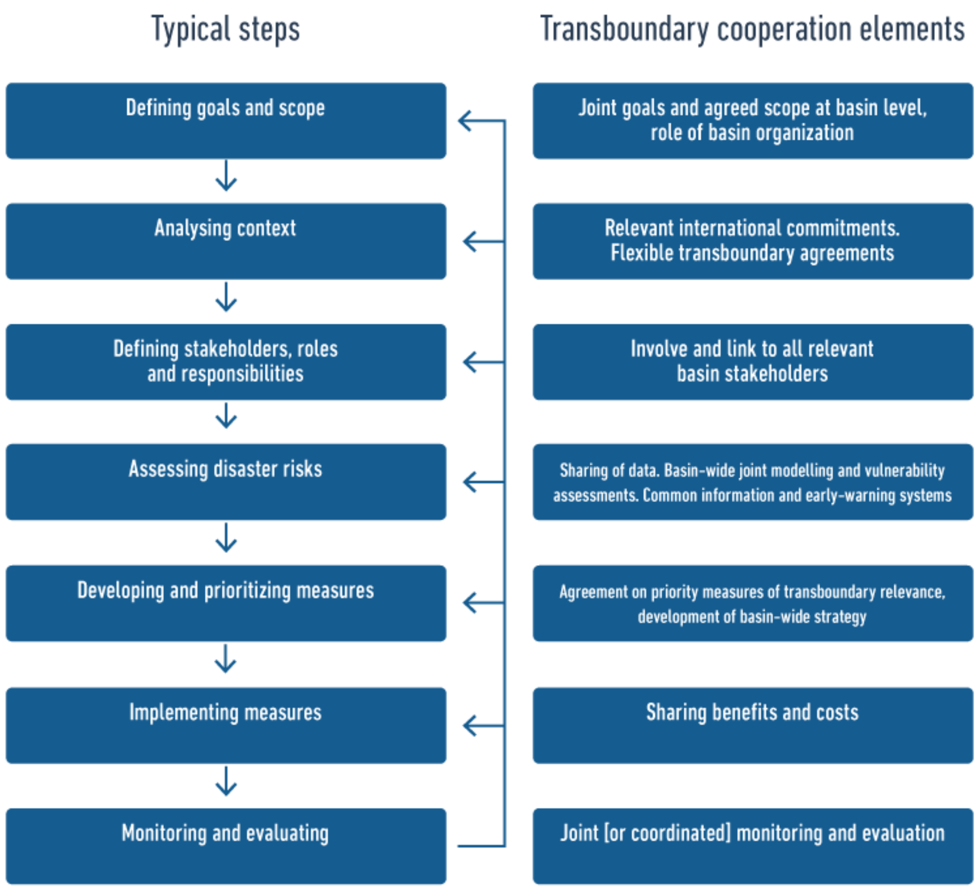
2.4 Structure of the guide

Many different structures exist to describe the steps in DRM. Figure 1 describes the steps involved in developing a DRM strategy as used in this guide. The steps include the following:

1. Define the goals and scope. This step will be described in Chapter 4.
2. Analysing the context. This includes the application of the different principles and approaches (Chapter 4), as well as the international legal context (Chapter 3).
3. Defining stakeholders, roles and responsibilities (Chapter 5).
4. Assessing disaster risks (Chapter 6).
5. Developing and prioritizing measures (Chapter 7).
6. Implementing measures (Chapter 8).
7. Monitoring and evaluation (Chapter 9).

All steps in the cycle should be embedded in an enabling environment that addresses the political, legal and institutional frameworks that may need to be assessed and adjusted to allow for DRM.

Figure 1. Transboundary cooperation elements for the typical disaster risk management steps



3. International commitments and legal framework

While the Sendai Framework is the most relevant international commitment towards DRR, a number of additional recent international frameworks also address disaster risks. For example, the SDG framework and the UNFCCC Paris Agreement include DRR as an integral part of sustainable development, addressing the intricate relations between climate change mitigation and adaptation and DRR.

International frameworks underpinning transboundary cooperation include the Water Convention serviced by the United Nations Economic Commission for Europe (UNECE)and the Convention on the Law of the Non-navigational Uses of International Watercourses (United Nations Watercourses Convention), which were finalized when DRR concepts were still under development. Although they do not include DRM as much as the SDGs and the Paris Agreement, they do contain provisions on emergency situations and hazardous substances. More detailed descriptions of other conventions that relate to disaster risk reduction are given in the sections below.

3.1 Sendai Framework

The goal of the Sendai Framework for Disaster Risk Reduction is to prevent new and emerging disaster risks and to reduce existing disaster risks. The framework encourages countries to implement integrated and inclusive measures that prevent and reduce hazard exposure and vulnerability to current and newly emerging disasters, while increasing preparedness for response and recovery as a mechanism for integrating more holistic, adaptive and cooperative approaches that strengthen resilience.

Floods, droughts and storms are the most frequently occurring disaster events accounting for almost 90 per cent of the 1,000 most disastrous events since 1990 (WCDRR, 2014). Moreover, damage from water-related disasters can in economic terms amount to 15 per cent of annual GDP for certain countries (UNISDR, 2015). The Sendai Framework provisions relative to water therefore aims:

(a) ‘To support, as appropriate, the efforts of relevant United Nations entities to strengthen and implement global mechanisms on hydro-meteorological issues in order to raise awareness and improve understanding of water-related disaster risks and their impact on society, and advance strategies for disaster risk reduction upon the request of States’. (para.34.(e))

The framework also stresses the importance of transboundary cooperation (UNISDR, 2015):

(b) ‘International, regional, sub regional and transboundary cooperation remains pivotal in supporting the efforts of States, their national and local authorities, as well as communities and businesses, to reduce disaster risk’. (para.8)
(c) ‘Each State has the primary responsibility to prevent and reduce disaster risk, including through international, regional, sub regional, transboundary and bilateral cooperation’. (para.19.(a))
(d) ‘To guide action at the regional level through agreed regional and subregional strategies and mechanisms for cooperation for disaster risk reduction, as appropriate, in the light of the present Framework, in order to foster more efficient planning, create common information systems and exchange good practices and programmes for cooperation and capacity development, in particular to address common and transboundary disaster risks’. (para.28(a))

(e) 'To promote transboundary cooperation to enable policy and planning for the implementation of ecosystem-based approaches with regard to shared resources, such as within river basins and along coastlines, to build resilience and reduce disaster risk, including epidemic and displacement risk'. (para.28(d))

The framework takes an explicit holistic approach to address the interconnectedness of various types of biophysical systems and the relation between social and biophysical systems (UNISDR, 2015):

(f) 'To attain the expected outcome, the following goal must be pursued: Prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience'. (para.17)
(g) 'The development, strengthening and implementation of relevant policies, plans, practices and mechanisms need to aim at coherence, as appropriate, across sustainable development and growth, food security, health and safety, climate change and variability, environmental management and disaster risk reduction agendas. Disaster risk reduction is essential to achieve sustainable development'. (para.19(h))
(h) 'To foster collaboration across global and regional mechanisms and institutions for the implementation and coherence of instruments and tools relevant to disaster risk reduction, such as for climate change, biodiversity, sustainable development, poverty eradication, environment'. (para.28(b))
(i) 'To promote the mainstreaming of disaster risk assessment, mapping and management into rural development planning and management of, inter alia, mountains, rivers, coastal floodplain areas, drylands, wetlands and all other areas prone to droughts and flooding, including through the identification of areas that are safe for human settlement and at the same time preserving ecosystem functions that help reduce risks'. (para.30(g))
(j) 'To strengthen the sustainable use and management of ecosystems and implement integrated environmental and natural resource management approaches that incorporate disaster risk reduction'. (para.30(n))

Such a holistic approach has been similarly fundamental in water resources management (both in national and transboundary contexts). The Sendai Framework encourages shared, evidence-based assessments of (disaster) risks and strong stakeholder engagement; both elements are strongly promoted in transboundary water management (UNISDR, 2015):

(k) 'To promote real-time access to reliable data, make use of space and in situ information, including geographic information systems (GIS), and use information and communications technology innovations to enhance measurement tools and the collection, analysis and dissemination of data'. (para.24(f))
(l) 'To promote and improve dialogue and cooperation among scientific and technological communities, other relevant stakeholders and policymakers in order to facilitate a science-policy interface for effective decision-making in disaster risk management'. (para.24(h))
(m) 'To enhance the development and dissemination of science-based methodologies and tools to record and share disaster losses and relevant disaggregated data and statistics, as well as to strengthen disaster risk modelling, assessment, mapping, monitoring and multi-hazard early warning systems'. (para.25(a))

(n) 'To promote and enhance, through international cooperation, including technology transfer, access to and the sharing and use of non-sensitive data, information, as appropriate, communications and geospatial and space-based technologies and related services. Maintain and strengthen in situ and remotely-sensed earth and climate observations…'. (para.25(c))
(o) 'To enhance the scientific and technical work on disaster risk reduction and its mobilization through the coordination of existing networks and scientific research institutions at all levels and all regions with the support of the UNISDR Scientific and Technical Advisory Group in order to: strengthen the evidence-base in support of the implementation of this framework; promote scientific research of disaster risk patterns, causes and impacts; disseminate risk information with the best use of geospatial information technology'. (para.25(g))

Finally, at the United Nations General Assembly on 20 December 2017, the countries acknowledged 'that water is essential to the achievement of the Sustainable Development Goals, and that water-related disasters and multidimensional hazards threaten lives, livelihoods, agriculture and basic service infrastructure and cause substantial socioeconomic damage and losses, and that sustainable and integrated water resource management is necessary for successful disaster preparedness, disaster risk reduction and climate change adaptation, and in this regard invites all countries to integrate land and water management, including for floods and droughts, into their national and subnational planning and management processes'. (para.13)[3]

Sustainable Development Goals

On 25 September 2015, the 194 United Nations Member States adopted the 2030 Development Agenda titled 'Transforming our world: the 2030 Agenda for Sustainable Development', popularly known as the Sustainable Development Goals[4]. This international framework contains 17 goals and 169 targets aimed at achieving inclusive social development, environmental sustainability, inclusive economic development, and peace and security. Where the SDGs mainly target the national level, it is recommended to include the transboundary aspects in attaining the goals. The most relevant goals for this guide include:

- Target 6.3, that aims to minimize the release of hazardous chemicals and materials.
- Target 6.5, that aims at implementing IWRM at all levels including through transboundary cooperation, which links well with the Sendai Framework articles that promote transboundary cooperation. Although the Sendai Framework does not explicitly mention IWRM as a means to address transboundary disaster risks, many of its provisions contain elements, strategies and methodologies that are very common to IWRM (see section 2.1.1).
- Target 6.6, to protect and restore water-related ecosystems including mountains, forests, wetlands, rivers, aquifers and lakes, which supports the goal by providing nature-based solutions to disaster risks management, and links well with IWRM practices.
- Target 11.5, that aims to significantly reduce the number of deaths and the number of people affected, and substantially decrease the direct economic losses (relative to global gross domestic product) caused by disasters, including those that are water-related, with a focus on protecting the poor and vulnerable.
- Target 11.B, that aims to substantially increase the number of cities and human

[3] Available from http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/72/218
[4] More information available from https://sustainabledevelopment.un.org/

settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and to develop and implement—in line with the Sendai Framework for Disaster Risk Reduction 2015–2030—a holistic disaster risk management approach at all levels.

- All the targets of Goal 13 on 'Climate action' that can be linked to the Sendai Framework, especially target 13.1 that calls for strengthening resilience and adaptive capacity to disasters.
- Goal 15, that aims to protect, restore and promote the sustainable use of terrestrial ecosystems. The goal reinforces the need to protect ecosystem services that includes vital hazard regulating services, and aims to reverse land degradation, which is seen as a key driver for disasters.

The Paris Agreement

The Paris Agreement for Climate Change[5] under the UNFCCC is the successor of the Kyoto Protocol. The Paris Agreement is legally binding and was adopted in December 2015 and signed in April 2016. It contains targets for restricting global warming up to 1.5°C to 2°C, as well as long-term goals to achieve climate resilience via adaptive measures. The Agreement also contains provisions that address loss compensation.

As climate change is known to develop new kinds of disaster risks and/or intensify current disaster risks, mitigation is an ultimate but long-term disaster risk prevention measure. But even under strong reductions of greenhouse gases the global climate will change. Therefore, DRR and climate change adaptation (CCA) under a changing climate will remain necessary.

The Paris Agreement acknowledges the Sendai Framework in its preamble. Articles 7 and 8 frame climate change risk in such a way that it relates well to the concepts and principles of the Sendai Framework. These articles also contain many provisions considered essential within IWRM and transboundary water resources management such as:

- Strengthening the knowledge base.
- Sharing of information, knowledge and experiences.
- Monitoring and evaluation of plans and policies.
- Developing both socioeconomic and ecological resilience.

While the Paris Agreement mentions the importance of regional cooperation in adaptation, the UNFCCC did not originally specifically aim at enabling transboundary climate change adaptation. Nor is the UNFCCC equipped to prevent and peacefully settle the types of disputes that may arise between watercourse States, which may increase under climate change. To enable this, other Conventions are essential, as described in the next section.

Water Convention

The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention)[6] serviced by the UNECE strengthens transboundary water cooperation and measures for the ecologically-sound management and protection of transboundary surface waters and groundwaters. The Convention fosters the implementation of IWRM, in particular, the basin approach. It was adopted in 1992 and entered into force in 1996. The Water Convention started as a regional convention but was opened up to countries outside the UNECE region in 2016. In 2018, Chad acceded to the Convention as the first country from

[5] Available from https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf
[6] More information available from https://www.unece.org/env/water/text/text.html

outside the UNECE region. Most UNECE countries with transboundary basins are Parties to the Convention.

Article 2 of the Water Convention contains the general provisions:

1. The Parties shall take all appropriate measures to prevent, control and reduce any transboundary impact.[7]
2. The Parties shall, in particular, take all appropriate measures:
   (a) To prevent, control and reduce pollution of waters causing or likely to cause transboundary impact;
   (b) To ensure that transboundary waters are used with the aim of ecologically sound and rational water management, conservation of water resources and environmental protection;
   (c) To ensure that transboundary waters are used in a reasonable and equitable way, taking into particular account their transboundary character, in the case of activities which cause or are likely to cause transboundary impact;
   (d) To ensure conservation and, where necessary, restoration of ecosystems.
3. Measures for the prevention, control and reduction of water pollution shall be taken, where possible, at source.
4. These measures shall not directly or indirectly result in a transfer of pollution to other parts of the environment.

Although not framed in the typical DRR language, as used for example in the Sendai Framework, the Water Convention does address transboundary pollution, which is a water-related disaster risk, as well as water-related disasters more broadly, especially floods but also droughts. For example, Article 11 on joint monitoring and assessment states, "[..] the Riparian Parties shall establish and implement joint programmes for monitoring the conditions of transboundary waters, including floods and ice drifts, as well as transboundary impact."

Addressing water-related disasters and their transboundary dimension was a priority for Parties from the outset. Already in 2000, a Task Force on Sustainable Flood Prevention was created, which was transformed into a Task Force on Water and Climate in 2006. In that framework, a series of useful tools were developed to improve transboundary disaster risk management. These include, among others, Guidelines on Sustainable Flood Prevention[8], Model Provisions on Transboundary Flood Management[9], Strategies for Monitoring and Assessment of Transboundary Rivers, Lakes and Groundwaters[10], Transboundary Flood Risk Management: Experiences from the UNECE region[11], Guidance on Water and Adaptation to Climate Change[12], Guidance on Water Supply and Sanitation in Extreme Weather Events[13], and Model Provisions on Transboundary Groundwaters[14]. Moreover, a Policy Guidance Note on the Benefits of Transboundary Water Cooperation: Identification, Assessment and Communication[15] was developed to underpin the benefits that cooperation can bring about. These are the main soft law tools for addressing disasters under the Convention.

The Task Force on Water and Climate, led in 2018 by the Netherlands and Switzerland, has

[7] Including those resulting from water-related disasters.
[8] Available from https://www.unece.org/index.php?id=12617
[9] Available from https://www.unece.org/fileadmin/DAM/env/documents/2006/wat/ece.mp.wat.19_ADD_1_E.pdf
[10] Available from https://www.unece.org/index.php?id=11683
[11] Available from https://www.unece.org/index.php?id=11654
[12] Available from https://www.unece.org/index.php?id=11658
[13] Available from https://www.unece.org/index.php?id=29338
[14] Available from https://www.unece.org/index.php?id=35126
[15] Available from https://www.unece.org/index.php?id=41340

worked since its creation in 2006 on promoting transboundary cooperation in climate change adaptation and disaster risk reduction. The Task Force supports countries in developing transboundary adaptation strategies though guidance, projects on the ground, and the exchange of experiences. Following the development of the Guidance on Water and Adaptation to Climate Change[16] in 2007–2009 the Task Force has promoted exchanges of experience by organizing annual workshops focused on different aspects of water, climate and disaster such as developing vulnerability assessments and adaptation strategies, selecting and implementing adaptation measures, ecosystem-based adaptation, cross-sectoral cooperation, and financing climate change adaptation and disaster risk reduction.

The Global network of basins working on climate change adaptation, established in 2013 by the UNECE in cooperation with the International Network of Basin Organizations (INBO), promotes experience and knowledge exchange in the fields of disaster risk reduction and climate change adaptation, especially in transboundary basins. Currently, the Global network includes 16 member basins, including from outside the UNECE region, such as the Chu-Talas, Dniester, Neman, Rhine, Mekong, Niger, Sava, Congo, and Senegal basins. The network members work together to develop solutions for water management that would reduce risks of disasters, along with other benefits.

Since 2010 pilot projects have been implemented by UNECE in cooperation with such partners as the Organization for Security and Co-operation in Europe (OSCE) and the United Nations Development Programme (UNDP) on the Dniester, Neman, Chu Talas and Sava basins, which aim to increase the adaptive capacity of the concerned countries and to prevent conflicts. For example, in the Sava basin, a programme for the development of the first flood risk management plan has been developed and has now been finalized. In the Dniester basin, transboundary flood risk has been reduced by mapping areas at risk, developing a basin-wide vulnerability assessment and adaptation strategy, and implementing adaptation measures such as reforestation, improvement of information exchange, setting up monitoring systems and developing local flood risk plans.

Recently, the Water Convention has also started work on helping basins in financing climate change adaptation measures, for example by organizing a training with partners on preparing bankable projects for climate change adaptation in transboundary basins.

A series of participatory basin-level assessments of intersectoral links, trade-offs and benefits in the water-food-energy-ecosystems nexus developed under the Convention since 2014[17] demonstrates the value of transboundary cooperation to control risks. For instance, one study shows that coordinated flow regulation in the Drina Basin is not only crucial for minimizing damage from flooding but it also benefits electricity generation from hydropower plants. According to another study by UNECE, coordinating joint investments in flood protection and energy infrastructure in the Alazani/Ganykh Basin would have the greatest benefits, and improving access to modern energy sources with appropriate policy measures would reduce exposure to flood damage by limiting deforestation.

United Nations Watercourses Convention

The United Nations Convention on the Law of the Non-navigational Uses of International Watercourses (Watercourses Convention) is a global treaty that was adopted in 1997 and entered

[16] Available from https://www.unece.org/index.php?id=11658

[17] Reconciling resource uses in transboundary basins: assessment of the water-food-energy-ecosystems nexus (UNECE, 2015), and technical reports on the Drina and Alazani/Ganykh River Basins. Available from http://www.unece.org/env/water/publications/pub.html

into force in 2014. It is a framework convention governing international watercourses. Similar to the UNECE Water Convention, it was developed before the current DRR concepts matured. However, it does contain articles that relate to disaster risk management:

- Article 11 states that “Watercourse states shall exchange information and consult each other and, if necessary, negotiate on the possible effects of planned measures on the condition of an international watercourse.” This does include informing each other on measures that can cause downstream disaster risks like dam building that increases low flow and drought probabilities downstream.
- Article 27 states that “Watercourse states shall, individually and, where appropriate, jointly, take all appropriate measures to prevent or mitigate conditions related to an international watercourse that may be harmful to other watercourse states, whether resulting from natural causes or human conduct, such as flood or ice conditions, water-borne diseases, siltation, erosion, salt-water intrusion, drought or desertification.”
- Article 28 deals with emergency situations and states that “‘emergency’ means a situation that causes or poses an imminent threat of causing, serious harm to watercourse states or other states and that results suddenly from natural causes, such as floods, the breaking up of ice, landslides or earthquakes, or from human conduct, such as industrial accidents.”

Ramsar Convention

The Convention on Wetlands, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources. The Convention was adopted in the Iranian city of Ramsar in 1971 and came into force in 1975.

To improve the integration of wetlands into river basin management, attention needs to focus on three major areas of activity:

- A supportive policy, legislative and institutional environment that promotes cooperation between sectors and sectoral institutions, and among stakeholder groups.
- Communication, education, participation and awareness (CEPA) programmes to support communication of policy and operational needs and objectives across different sectors, primarily the water and wetlands sectors, and among different stakeholder groups.

Sequencing and synchronization of planning and management activities in different sectors responsible for land use, water resources and wetlands (Ramsar Convention Secretariat, 2010).

At the 12th Meeting of the Conference of the Parties (COP) to the Ramsar Convention in 2015, Resolution XII.13[18] on ‘Wetlands and disaster risk reduction’ was adopted. The resolution acknowledges “the vital role of wetland ecosystems, most especially healthy and well-managed wetlands, in reducing disaster risk, by acting as natural buffers or protective barriers” and recognizes “that fully functioning wetland ecosystems enhance local resilience against disasters by providing fresh water and important products and by sustaining the lives and livelihoods of local populations and biodiversity.” The resolution bridges the international frameworks that focus on DRR/CCA and the ones dealing with IWRM and transboundary water management, and brings nature-based solutions to the fore.

This resolution reiterates that “the Sendai Framework for Disaster Risk Reduction 2015–2030 acknowledges declining ecosystems as an underlying disaster risk driver, and recognizes the importance of strengthened sustainable use and management of ecosystems and the

[18] Available from http://www.ramsar.org/sites/default/files/documents/library/cop12_dr13_disaster_risk_reduction_e.pdf

implementation of integrated environmental and natural resource management approaches that incorporate disaster risk reduction." (Article 9)

It also relates disaster risk reduction to the concept of ecosystem services (goods and services people may benefit from nature). Disaster risk reduction type of ecosystem services are provided through wetlands "by acting as natural buffers or protective barriers, for instance through mitigating land erosion, the impact from dust and sandstorms, floods, tidal surges, tsunamis and landslides, and by storing large volumes of water, thereby reducing peak flood flow during the wet season, while maximizing water storage during the dry season." (Article 6)

The resolution asks parties to include DRR intervention in wetland management plans and to include wetlands as an ecosystem-based solution in DRR plans. This introduces the concept of nature-based or ecosystem-based solutions that try to mitigate disaster risk impacts by smartly using landscape entities such as the forested water towers or hinterlands, wetlands, river floodplains and coastal mangroves and not by means of engineered or hard infrastructure interventions such as dams and dikes.

Industrial Accidents Convention

The 41 Parties to the UNECE Convention on the Transboundary Effects of Industrial Accidents[19]—from Western, Eastern and South-Eastern Europe, the Caucasus and Central Asia —work together to prevent, prepare for and respond to industrial accidents, especially those with transboundary consequences. These accidents may be the result of human activity or triggered by natural disasters. Under the Industrial Accidents Convention, Parties have to work on two levels:

- At the national level, by setting up early warning systems, mandating the operators of large industrial installations to take precautionary measures, or by preparing contingency plans for immediate response. This includes public participation in the decision-making process and in emergency planning and exercises.
- At the international level, on joint emergency plans, mutual assistance and public awareness, as well as on ensuring that the public can take part in decision-making. Parties to the Convention also exchange information and technology, and identify actions that may save lives in the event of an accident, such as how to facilitate the transport of equipment and personnel across borders during emergencies.

DRR related activities under the Industrial Accidents Convention include:

- The development of a Words into Action guide on technological and human-induced hazards, in cooperation with UNISDR, the Joint UNEP/OCHA Environment Unit and the OECD.
- The facilitation and implementation of transboundary preparedness exercises, e.g. a trilateral field exercise in the Danube Delta region between the Republic of Moldova, Romania and Ukraine in September 2015[20], and a bilateral exercise between Poland and Germany on the Oder River in September 2017.[21]
- Capacity-building activities to support the identification and notification of hazardous activities in Central Asia[22], South-Eastern Europe[23] and the Caucasus and Eastern

[19] More information available from http://www.unece.org/env/teia.html
[20] More information available from http://www.unece.org/env/teia/ap/ddp.html
[21] More information available from http://www.unece.org/index.php?id=45431
[22] More information available from http://www.unece.org/index.php?id=39866
[23] More information available from http://www.unece.org/index.php?id=44724

Europe[24] under the Convention's Assistance Programme.

- Support to countries in strengthening industrial safety governance by strengthening inter-institutional coordination mechanisms and supporting policymaking on industrial safety and technological disaster risk reduction, among others, through the development of national self-assessments and action plans under the Convention's Assistance Programme, and their coordination with national strategies and action plans for disaster risk reduction.
- Support to countries in the application of guidance materials developed under the Convention, e.g. a Checklist on contingency planning for accidents affecting transboundary waters[25] , Draft guidance on land-use planning[26], and Safety guidelines and good practices for Tailings Management Facilities[27], Safety guidelines and good practices for Pipelines[28], and Safety guidelines and good industry practices for Oil Terminals.[29]

The Industrial Accidents Convention and the Water Convention share an Ad Hoc Joint Expert Group on Water and Industrial Accidents (JEG), which was established in 1998 to prevent accidental water pollution and to support countries in mitigating transboundary effects by strengthening prevention, preparedness and response measures. The Joint Expert Group has produced several guidance documents and checklists on a number of subjects, including on the safety of pipelines, oil terminals and tailing management facilities (as noted earlier). Draft Safety Guidelines and Good Practices for the Management and Retention of Firefighting Water are under development and due for publication in the 2019–2020 biennium. Furthermore, the Joint Expert Group supports countries in strengthening preparedness for accidental water pollution, among other forms of support, through the organization of response exercises at transboundary rivers.

As the only legal instrument under the umbrella of the United Nations addressing transboundary cooperation for industrial accident prevention, preparedness and response, the Convention's legal framework, tools and guidance materials can inspire countries in progressing towards the implementation of the Sendai Framework in the area of technological disaster risk reduction, including countries beyond the UNECE region.

United Nations Convention to Combat Desertification

The United Nations Convention to Combat Desertification (UNCCD)[30] was established in 1994 and is the sole legally binding international agreement linking environment and development to sustainable land management. The Convention addresses specifically the arid, semi-arid and dry sub-humid areas known as the drylands where some of the most vulnerable ecosystems and peoples are found. The 196 Parties to the Convention work together to improve the living conditions for people in drylands, to maintain and restore land and soil productivity, and to mitigate the impacts of drought.

The UNCCD 2018–2030 Strategic Framework states that desertification, land degradation and drought contribute to and aggravate economic, social and environmental problems such as poverty, poor health, lack of food security, biodiversity loss, water scarcity, reduced resilience to climate change and forced migration. They continue to pose serious challenges to the sustainable development of all countries, particularly affected countries. Addressing these issues

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[24] More information available from http://www.unece.org/index.php?id=44839
[25] Available from http://www.unece.org/index.php?id=44290
[26] Available from http://www.unece.org/index.php?id=41522
[27] Available from http://www.unece.org/index.php?id=36132
[28] Available from http://www.unece.org/index.php?id=41068
[29] Available from http://www.unece.org/index.php?id=41066
[30] More information available from http://www2.unccd.int/

will involve long term integrated strategies that simultaneously focus on the improved productivity of land, and the rehabilitation, conservation and sustainable management of land and water resources.

Strategic objective 3 of the Strategic Framework responds to DRR and CCA, "To mitigate, adapt to, and manage the effects of drought in order to enhance resilience of vulnerable populations and ecosystems." Actions to reach the strategic objectives include the mobilization of financial and non-financial resources, and the establishment of policies and enabling environments. Concrete actions include:

- Develop and operationalize drought risk management, monitoring and early warning systems and safety-net programmes, as appropriate.
- Establish systems for sharing information and knowledge, and facilitate networking on best practices and approaches to drought management.

Espoo Convention

At the transboundary level, the UNECE Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention)[31] lays down the general obligation of States to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across boundaries. The Espoo Convention was complemented by the Protocol on Strategic Environmental Assessment to ensure that individual Parties integrate environmental assessment into their plans and programmes at the earliest stages. Both instruments aim to prevent and mitigate damage to the environment and human health from economic and regional development before it occurs.

Most countries in the UNECE region have adopted and applied the Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) policy instruments to help steer large scale land use and water allocation planning and to assess impacts of large scale infrastructural interventions. While the EIA is a formal process used to predict the environmental consequences of a project or an event, the SEA is a systematic process for evaluating the environmental and health consequences of proposed Government plans and programmes, and to the appropriate extent, also proposals and legislation to ensure that environment and health matters are explicitly factored into the decision-making process, next to economic and social considerations.

Both EIA and SEA are well established environmental decision-making tools that have been applied regularly within the field of IWRM and river basin planning. The tools can be expanded relatively simply to include the assessment of potential disaster risks of plans, policies and proposals. This allows for the expansion of EIAs and SEAs to include ex ante disaster risk assessments and the definition of mitigation measures to avoid disaster risks from policies and plans, and allows the crucial mainstreaming of DRR into conventional land and water use planning and management (Slootweg, 2009; Ludwig and Swart, 2010). Despite the conceptual logic for such an integration only few countries have adapted their EIA/SEA policies. A clear example of such adapted guidelines was developed by the Department of Environment and Natural Resource in the Philippines. The Environmental Impact Assessment Technical Guidelines (Republic of the Philippines, 2011) have currently been revised to integrate disaster risk reduction and climate change adaptation approaches and concepts.

[31] More information available from http://www.unece.org/env/eia/welcome.html

4. Main principles and approaches

This guide builds upon a range of principles and approaches that are relevant for water management and includes water governance, the concept of mainstreaming, IWRM and the role of ecosystems in water management. This also relates to the links between water management and sectors that are important water users. The principles and approaches will be described in this chapter.

4.1 Governance principles

Governance refers to the actions, processes, traditions and institutions by which authority is exercised and collective decisions are taken and implemented. Risk governance applies the principles of governance to the identification, assessment, management, evaluation and communication of risks in the context of plural values and distributed authority. It includes all the important actors involved, and considers their rules, conventions and processes. It is thus concerned with how relevant risk information is collected, analysed, understood and communicated, and how management decisions are taken and communicated (IRGC, 2017). Risk governance thus sets the basis for disaster risk management.

Integrated water management is a complex process that tries to achieve a balance between a range of interests, represented by various institutions with different beliefs, values, norms and cultural habits. It also requires coordination over various administrative units at local, regional and national levels, including municipalities, counties and provinces, among others. International transboundary cooperation adds to this complexity through differences in language and legal frameworks, as well as different historical and cultural backgrounds (Timmerman and Langaas, 2005). Water governance is therefore essential in coordinating water and disaster risk management.

At the local level, planning decisions made in one local government can impact water resources in another local government sharing the same water basin and would therefore require coordination between cities. Planning decisions can thus impact upstream and/or downstream settlements and would need to involve stakeholders in both places.[32]

At the international level, transboundary cooperation in water management heavily depends on circumstances at the national level. Weak social and institutional capacity, poor legal and policy frameworks, and bad management practices have huge consequences in the transboundary context where they are further amplified by differences between riparian countries. Based on a review of water governance arrangements and in-depth national multi-stakeholder policy dialogues in a range of countries, the Organisation for Economic Co-operation and Development (OECD) developed 12 water governance principles that are intended to contribute towards tangible and outcome-oriented public policies (Table 1) (OECD, 2015*b*). These principles are relevant both in the national and international context. Examples of how these OECD principles can be applied in transboundary water management and climate adaptation is described in Timmerman *et al*. (2017).

[32] Also refer to the IWA Principles for Water Wise Cities available from http://www.iwa-network.org/wp-content/uploads/2016/10/IWA_Brochure_Water_Wise_Communities_SCREEN.pdf

Table 1. OECD Principles on Water Governance

Enhancing the effectiveness of water governance
Principle 1. Clearly allocate and distinguish roles and responsibilities for water policymaking, policy implementation, operational management and regulation, and foster coordination across these responsible authorities. Principle 2. Manage water at the appropriate scale(s) within integrated basin governance systems to reflect local conditions, and foster coordination between the different scales. Principle 3. Encourage policy coherence through effective cross-sectoral coordination, especially between policies for water and the environment, health, energy, agriculture, industry, spatial planning and land use. Principle 4. Adapt the level of capacity of responsible authorities to the complexity of water challenges to be met, and to the set of competencies required to carry out their duties.
Enhancing the efficiency of water governance
Principle 5. Produce, update, and share timely, consistent, comparable and policy-relevant water and water-related data and information, and use it to guide, assess and improve water policy. Principle 6. Ensure that governance arrangements help mobilize water finance and allocate financial resources in an efficient, transparent and timely manner. Principle 7. Ensure that sound water management regulatory frameworks are effectively implemented and enforced in pursuit of the public interest. Principle 8. Promote the adoption and implementation of innovative water governance practices across responsible authorities, levels of government and relevant stakeholders.
Enhancing trust and engagement in water governance
Principle 9. Mainstream integrity and transparency practices across water policies, water institutions and water governance frameworks for greater accountability and trust in decision-making. Principle 10. Promote stakeholder engagement for informed and outcome-oriented contributions to water policy design and implementation. Principle 11. Encourage water governance frameworks that help manage trade-offs across water users, rural and urban areas, and generations. Principle 12. Promote regular monitoring and evaluation of water policy and governance where appropriate, share the results with the public and make adjustments when needed.

Source: OECD, 2015*b*

In order to implement a DRM strategy in a transboundary IWRM context, an understanding of the enabling environment is needed, i.e. knowledge of the existing policy, legal and institutional framework. This requires an analysis to evaluate whether the water-related policies, legal setting and the institutions will enable the implementation of the strategy. With regard to floods for example, the Rapid Legal Assessment Tool (RLAT)[33] will enable a team of experts in the country to test the existing legal frameworks for compatibility with the concept of Integrated Flood Management (IFM) and to initiate and guide an appropriate reform process. If gaps or barriers in the enabling environment are identified, actions should be developed to overcome these gaps and barriers. Often, different institutions are involved in DRM and water management (see table 2 in section 5.1), which makes finding the proper institution complicated. In addition, stakeholder engagement is needed to reduce the risks associated with water-related disasters within the context of the (transboundary) basin. Overall, the analysis includes an assessment of the policies and legal arrangements in place, and the institutions, stakeholders and their instruments (basin plan, national disaster plan, climate initiative, standing legislation, and so on) to map the landscape and identify the entry points for mainstreaming DRR.

[33] More information available from: http://www.floodmanagement.info/publications/policy/ifm_legal_aspects/Legal_and_Institutional_Aspects_of_IFM_En.pdf

Box 1. Developing an adaptation strategy in the Lower Mekong Basin

In 2015–2016, the Mekong River Commission (MRC) Climate Change and Adaptation Initiative (CCAI) formulated the Mekong Adaptation Strategy and Action Plan (MASAP). The MASAP sets out strategic priorities and actions to address climate change risks at the basin level. In the process of formulation, the first important step was to conduct a policy analysis of climate change and adaptation in the Lower Mekong Basin (LMB). The policy analysis aimed to ensure that the MASAP is consistent with and does not contradict the national climate change policies of its Member Countries. The policy analysis comprised an analysis of the state of play on three main elements: policy setting, legal setting, and institutional setting. Furthermore, two additional elements were analysed, namely the information system and the financing system.

From the policy analysis, it was concluded that there is an enabling environment for the development and implementation of the MASAP. Minor issues in policies and legislation hindering implementation of the MASAP might occur over time but these are not prominent. One of the main hindrances to be addressed in the development of the MASAP is the limited availability of information, financial resources and the complexity of institutional settings. Regular updates of the MASAP are needed to ensure that the proposed strategic priorities and actions remain relevant in view of the policy, legal and institutional setting.

In the context that all LMB Member Countries prioritize climate change adaptation by signing various global climate change agreements, such as the Paris Agreement, and having their own national strategies and plans, the added values of the MASAP will focus on critical climate change adaptation aspects that need to be addressed at transboundary level, as well as positioning MRC as a leading regional institution in advancing the capacity of Member Countries in implementing their own national strategies (MRC, 2017).

For a coherent basin-wide adaptation strategy for MRC to contribute to the adaptation efforts of LMB countries and the minimization of negative impacts of current and future climate change in the basin, seven strategic priorities are identified:

1. Mainstream climate change into regional and national policies, programmes and plans.
2. Enhance regional and international cooperation and partnership on adaptation.
3. Enable implementation of transboundary and gender sensitive adaptation options.
4. Support access to adaptation finance.
5. Enhance monitoring, data collection and sharing.
6. Strengthen capacity in the development of climate change adaptation strategies and plans.
7. Improve outreach of MRC products on climate change and adaptation.

Under each strategic priority, several prioritized actions are set out as implementation steps, which contribute towards realizing the strategy. The strategic priorities and underlying actions focus on supporting MRC Member Countries in developing and implementing an adaptation strategy in an integrated way, accounting for the imperative cooperation in the LMB.

In identifying strategic priorities and their associated actions, the following aspects were taken into account: the goals, objectives and principles of the 1995 Mekong Agreement; the core functions of the MRC; the adaptation options identified and recommended from the CCAI basin-wide assessment of climate change impacts and vulnerability in the LMB; and the results of a regional policy review and relevant actions from the Basin Development Strategy (BDS) 2016-2020.

More information available from http://www.mrcmekong.org/assets/Uploads/MASAP-summary-final.pdf

4.2 Mainstreaming DRM measures in (transboundary) basins

DRR planning as well as CCA should be integrated into existing policy development in planning, programmes and budgeting across a broad range of economic sectors – a process generally called "mainstreaming". This process involves using or creating mechanisms that allow decision-makers to integrate future climate risks into all relevant ongoing policy interventions, planning, and management (Luers and Moser, 2006). It includes assessing the implications of disasters and climate change on any planned development action in all thematic practice areas and sectors at all levels, including the transboundary level, as an integral dimension of the design, implementation, monitoring and evaluation of policies and programmes. Moreover, the inclusion of transboundary impacts and opportunities of DRR in national strategies will extend the decision-space, i.e. broaden the range of possible solutions. Mainstreaming DRR and CCA into international, national and regional sectoral policies is important to reduce the vulnerability of sectors in the long term, such as agriculture, forests, biodiversity and the protection of ecosystems (including water), fisheries, energy, transport, drinking water and sanitation, and health. Mainstreaming must be carefully prepared and be based on solid scientific and economic analysis. For each policy area, a review of how policies could be refocused or amended to facilitate adaptation should be conducted (UNECE, 2009*a*; 2009*b*).

Mainstreaming DRR and CCA includes considering and addressing the risks associated with disasters and climate change in all processes of policymaking, planning, budgeting, implementation and monitoring. This requires an analysis of how potential risks and vulnerability could affect the implementation of policies, programmes and projects. Concurrently, it also analyses how these in turn could have an impact on vulnerability to hazards. This analysis should lead on to the adoption of appropriate measures to reduce potential risks and vulnerability where necessary, and thus treating risk reduction and adaptation as an integral part of all programme management processes rather than an end in itself (IFRC, 2013).

An important element of DRM is the concept of "build back better". This concept requires looking at future events when designing measures for recovery after a disaster. This forward looking approach should be incorporated into every DRM policy, strategy and plan to ensure that possible disasters from extreme events caused by climate change are taken into account. In this way, DRR and CCA can be combined.

Box 2. Mainstreaming climate change in the forest and biodiversity sector in Kyrgyzstan

The Climate Change Adaptation Programme and Action Plan for 2015–2017 for the forest and biodiversity sector in the Kyrgyz Republic serves as a sectoral policy document aimed at strengthening the resilience of the sector to the adverse effects of climate change on natural ecosystems and communities. The goals of the programme are: i) to incorporate climate change impacts into protected areas and forest enterprises management plans and practices, and involve forest communities into activities to strengthen the resilience of ecosystems and communities; ii) to promote the conservation and restoration of damaged natural ecosystems to strengthen their resilience to climate change; and iii) to increase the capacity and awareness of stakeholders of the forest and biodiversity sectors on climate change adaptation.

More information available from http://naturalresources-centralasia.org/flermoneca/assets/files/Climate%20Change%20Adaptation%20Programme%20and%20Action%20Plan%20%20for%202015-17%20for%20the%20Forest%20and%20Biodiversity%20Sector_EN.pdf

DRR and CCA mainstreaming will encounter barriers and challenges that includes bureaucratic organizational processes, lack of capacity and knowledge, high staff turnover, ineffective procedures for retaining organizational memory, and a culture of working in 'silos'. At a practical level, there are also such disparate issues as unclear roles and responsibilities and time constraints when it comes to DRR and CCA mainstreaming. The lack of funding for cross-cutting initiatives is another hurdle (IFRC, 2013).

Furthermore, incorporating flexibility into water management systems can help to mainstream DRM. Examples include systems designed to fail, such as the use of levees that can be removed in the event of a flood to submerge the surrounding farmland, which is coupled with an insurance programme for farmers. This is also an example of combining structural with non-structural measures. Another example can be seen in drought systems that use a staged set of drought management restriction rules that become more stringent as the drought evolves.

The cost of adapting water management to disaster risks and climate change will likely add to the already substantial financing gap for water systems. Adaptation and risk management costs for water could be substantial, especially for flood protection. Nevertheless, many of the investments needed could take place within normal investment replacement cycles or could be added on top of planned investments. Moreover, on average, the benefits of investing in DRM outweigh the costs and can amount to around four times the cost in terms of prevented and reduced losses (Mechler, 2016). It is difficult and often impractical to attempt to separate out the marginal additional costs related to adaptation from those due to a broader range of pressures on water systems resulting from a wide range of drivers (UNECE, 2015).

4.3 IWRM approach towards DRR

IWRM is recognized internationally as the standard water management approach. A 2012 UN-Water study found that 84 per cent of the 134 participating countries had engaged in the implementation of IWRM in some form. The study found that 65 per cent of the participating countries had developed IWRM plans and 75 per cent of the participants had ranked DRR as a key priority for their IWRM activities (UNEP, 2012).

The need for integrated water management has evolved over the past century having arisen from the increasing human activities in the river basin areas of major rivers. Consequently, a comprehensive, coordinated and systematic process of planning, control, organization, leadership and management within the basin has developed in many basins based on the starting point that water is one of the primary components of landscape structure and an integral part of the ecosystem, as well as a socioeconomic resource. A multidisciplinary approach is thus required that integrates water supply and sewerage systems, agriculture, industry, residential development, water works, transportation, recreation, fishing and other activities. It also requires coordination between the sectors and adaptation of different planning and management systems within an individual basin (Moravcová *et al.*, 2016).

Water is barely mentioned in the Sendai Framework and IWRM is not included as a key approach on how to implement DRR strategies. Nevertheless, many commonalities exist between IWRM and DRR. The Global Water Partnership (GWP) identifies the following commonalities:[34]

(a) both IWRM and DRR propose integrative and holistic approaches, in particular, taking a systems approach (e.g. connect land and water, biophysical systems to social, economic and political systems), and acknowledging scale issues,

[34] More information on the GWP IWRM Toolbox available from https://www.gwp.org/en/learn/iwrm-toolbox/About_IWRM_ToolBox/

(b) both approaches stimulate and prefer preventive measures over curative measures and acknowledge the importance of healthy ecosystems as a regulatory force,
(c) both approaches are inclusive in nature and explicitly address the needs, interests and capacities of vulnerable groups, the poor and marginalized,
(d) both approaches acknowledge the need for decentralized approaches and the importance of participatory approaches, involving all stakeholders at relevant levels of interventions, including women,
(e) both approaches propagate good governance under the responsibility of national governments,
(f) both approaches acknowledge the importance of understanding systems by means of data collection assessment and research.

Transboundary risk management should consequently be considered as a part of IWRM. General activities that are of special importance in transboundary basins include (UNECE, 2009*b*):

- Water balance for the entire basin: a proper understanding of the overall hydrological functioning of the basin is needed to ensure that actions and measures will lead to the expected outcomes.
- Good communication between riparian countries. This is more a political issue and partly a legal issue, but not so much a technical one. Informal meetings can be helpful in starting up communication.
- Joint problem definition and a common understanding of interests among all riparian countries are important for stimulating and improving transboundary cooperation. This includes issues on ecological functioning, reservoir and dam operations, and so on.
- Sharing hydro-meteorological data across borders is a fundamental basis for cooperation. Data sharing and also the quality and reliability of information needs to be improved in many cases to help reach a common understanding of the situation, among other things. Compatibility of data formats is an issue; the shared data must be incorporated into each country's early warning or decision support system.[35]
- Joint bodies such as river basin commissions can help facilitate international cooperation, including the sharing of data, as well as the elaboration of management plans, including River Basin Management Plans, Flood Risk Management Plans and Drought Management Plans. Where no transboundary river basin commissions exist, these should be established, preferably at a high institutional level and with political support so as to ensure sufficient funding for all joint activities.
- Technical cooperation at the transboundary level is in general more advanced than institutional and political cooperation. Institutional and political cooperation should therefore aim to keep pace with technical cooperation.
- A joint legal framework is needed to sustain technical cooperation. Formal agreements for cooperation should be flexible and be based on a cross-sectoral approach.
- Pilot projects and regional and subregional workshops on transboundary water management are a useful tool for exchanging good practices and for discussing problems and experiences.
- Capacity-building and training at both technical and the decision-making levels help to

[35] All World Meteorological Organization (WMO) Members (i.e. all countries in the world except Taiwan) have adopted Resolution 25 at the WMO 13th Congress General (1999) on the exchange of hydrological data, which states in part that "Members shall provide on a free and unrestricted basis those hydrological data and products which are necessary for the provision of services in support of the protection of life and property and for the well-being of all peoples."

improve both the knowledge base and international cooperation.

- Early warning. Combined meteorological and hydrological monitoring and forecasting systems can provide timely information on the extent and severity of extreme events. Imminent events can be detected at an early stage, allowing for timely responses. To this end, a basin-wide information and data exchange system is needed to ensure accurate information. Such a system includes a range of agreements, for example on data-exchange protocols, including frequency of exchange, contact points, warning levels, communication channels and so on. The system should be accompanied by a disaster preparedness and response system that prescribes the necessary action in case of a developing extreme event. Early warning should cover both quantity (floods and droughts) and quality (spills and accidents).

The modern eco-hydrological definition of good water management focuses on the natural flow regime and the necessary relationship between events and the sustainability of ecosystems and ecological health, i.e. ecosystems remain healthy when there is a certain level of variability. Water should therefore be managed with a view to maintaining variation and variability, including extreme events. However, from the DRR perspective, variability should be reduced (floods and droughts should be minimized in terms of influence and impact). Consequently, integrating IWRM and DRR includes maintaining variability.

Taking into account the many hazards propagated through water systems, often resulting from the mismanagement of land and water resources and even from non-water related disasters, the availability of clean and sufficient water is a key factor in survival and recovery. The importance of IWRM to DRR is therefore evident, and integrating DRR strategies in IWRM plans, policies and operations is therefore a logical step. Making use of the institutional frameworks that have been developed for IWRM implementation is a quick way of operationalizing parts of DRR strategies. As mentioned earlier, UNECE has developed the Model Provisions on Transboundary Flood Management[36] to support transboundary cooperation on flood risk management that presents example provisions for legal agreements that countries can use to develop bi- or multilateral agreements on flood management.

[36] More information available from https://digitallibrary.un.org/record/645887/

Box 3. Challenges for Integrated Water Resources Management in the Niger River Basin

Potential transboundary disaster risks such as floods, hydrological droughts and low flows, as well as contaminated water plumes are relatively easy to detect when meteorological monitoring and monitoring of water quantity and quality is in place and used for early warning purposes. However, some transboundary disaster impacts are less pronounced. This is especially the case with cascading impacts and/or when impacts transfer from water systems to other systems and only manifest with a delay.

The Inner Niger Delta in Mali illustrates some of these issues. The Delta is an inland delta of more than 30,000 km^2 in Mali in the Niger River Basin. A flood pulse (mostly resulting from precipitation falling in the Guinean highlands) annually propagates through the delta in the months from August to November, increasing flood levels up to 6 metres. During the flooding period the Sahelian barren landscape changes into a mosaic of braiding river channels, lakes and a multitude of ponds. This flooding is usually non-hazardous but it triggers all kinds of ecosystem functions delivering services and goods to the people in the delta on which they depend for subsistence and even survival.

When the flood pulse is less than average, which might result from less upstream precipitation but often results from upstream water allocation to generate hydropower and supply irrigation water, this does not necessarily lead to a classical drought disaster situation with dry wells and dying livestock. However, ecosystems dynamics change dramatically. Fish rejuvenation during such a low flow year is much lower, resulting in decreased fish catches the following year. Farmers applying flood recession agriculture need to shift to different (lower) parts of the floodplains to be able to grow their crops, requiring more from their scarce resources and time. Enlarging areas with low velocity or stagnant water increase the prevalence of waterborne and vector borne diseases. Taking into account the normally already high vulnerability of these livelihood groups in the delta, such changes in the provision of ecosystem services may prove disastrous, especially when they occur with greater frequency.

4.4 Ecosystem based approaches

A common thread running through earlier global policy climate agreements in 2015 is a clear recognition of the role that ecosystems play in safeguarding development gains, and in building resilience against disasters and climate change (PEDRR, 2016). The Sendai Framework clearly recognizes that degraded ecosystems are a contributing factor in the development of hazards and that they reduce the ability of landscapes and societies to absorb the shocks caused by hazards. In addition, ecosystem-based adaptation approaches are usually beneficial from a transboundary perspective.

The concept of ecosystem services is based on how humans benefit from ecosystems in the form of derived goods and received services. Some of these services are perceived as being able to reduce disaster risks. Examples of such ecosystem services are natural floodplain systems or meandering river systems that can store large volumes of water and reduce run-off, and hence are able to dampen out flood waves. The "Room for the River" work in the Netherlands is an example of the fundamental shift from increasing defenses to an ecosystem based approach that 'gives back' land to riparian and coastal systems. Disasters related to water quality (such as when climate change creates hypertrophic conditions, high levels of water salinity or anoxic waters) can often be mitigated through forest management by altering run-off conditions and improving water quality for riparian and lacustrine systems. In China, some lakes and wetlands have become so eutrophic that they have algal blooms in winter, displaying green ice. Forest management, together with improved sewage treatment and agricultural run-off, can help in this case. The slow release of water from densely vegetated backwater maintains certain levels of baseflow into the river, thus reducing the risk of drought development. Many of these examples can be found in Renaud *et al.* (2016). Nevertheless, from an eco-hydrological perspective, floods and droughts are normal and sometimes necessary to maintain certain ecosystems. They may also have other important co-benefits like fertilizing the soil or providing spawning areas. Consequently, there is a need to find a balance between a beneficial and a detrimental level of floods and drought.

The Partnership for Environment and Disaster Risk Reduction (PEDRR) is a global alliance of UN agencies, NGOs and specialist institutes that seeks to promote and scale-up the implementation of ecosystem-based disaster risk reduction, ensuring that it is mainstreamed in development planning at global, national and local levels in line with the Sendai Framework for Disaster Risk Reduction. The PEDRR developed an implementation strategy for ecosystem-based approaches within the Sendai Framework. Key messages from this strategy centered around a transboundary basin context and include:

- Degraded ecosystems (in general because of changed land use and land cover that influences water retention, recharge, run-off, and so on like floodplains with built infrastructure, silted up wetlands, deforested hinterland) are an important contributing factor for the onset of water-related disasters that can propagate downstream in transboundary systems.
- Ecosystems themselves such as wetlands can be heavily damaged from disasters, disturbing ecological balances and or even completely turning an ecosystem into a different regime. If people are depending locally on the goods and services from such damaged ecosystem then this may impact the sustainability of their livelihoods and their capacity to recover post-disaster.
- Ecosystem-based approaches in DRR and climate change adaptation include maintaining or restoring ecosystems to a good ecological state, protecting ecosystems from being damaged by disasters (especially those that provide high value in terms of ecosystem services), and using ecosystems as naturally ‘engineered’ landscapes to help lessen the impacts of hazards. Approaches like “Building with nature” and “Room for the River”, and the removal of drainage and the re-meandering of creeks and rivers that were canalized during phases of strong intensive agricultural development are all examples of the ecosystem-based approaches.
- To operationalize ecosystem approaches into DRR, one needs to integrate DRR (and climate change adaptation measures) into wetlands and other ecosystem management plans and vice-versa, i.e. one needs to include ecosystems and its services in all national and transboundary plans that deal with disaster risk reduction, climate change mitigation and adaptation, and sustainable development.

4.5 Nexus: links to related sectors like agriculture, energy, industry, land use and ecosystems

As previously mentioned, the current global agreements all adopt a holistic approach. Besides the more common integrated approaches dealing with water resources (IWRM) and natural resources (INRM), the so-called “water-food-energy-ecosystem nexus” adds a new paradigm to integration. At its core is the scarcity of natural resources and the interdependencies that result from making use of the same resource base, simultaneously trying to achieve water, food and energy security as well as ecological sustainability (Leck *et al.*, 2015). The nexus explicitly focuses on these complex relationships in order to find synergies and prevent unintended consequences, and at least show the possible trade-offs resulting from chosen development paths and how this results in distributional and equity effects. The lack of integration in governance, such as departmentalization, silo-thinking and sectoral target setting, programming, budgeting and monitoring, are nevertheless major challenges with regard to the nexus approach.

The nexus approach is an interesting concept to apply in a transboundary context in that it looks at interdependencies and trade-offs, and also addresses transboundary DRR aspects. Evidently one of the most obvious water related interdependencies is the upstream-downstream relationship. An upstream country that unilaterally decides to realize sovereign food and energy security by means of dams and irrigation schemes can greatly influence hydrological regimes downstream such that the likelihood of droughts, for example, changes significantly. Hence, non-cooperation can result in increased disaster risks. Note that such upstream-downstream issues can also occur within a country. Attempts at bi- or even multilateral cooperation in realizing water, food and energy security in a basin-wide context can result in the optimal shared use of scarce land and water resources based on the countries' comparative advantages and their natural resources. Such transboundary nexus cooperation reduces the context of disaster risk across a wider region and provides societal resilience that helps overcome disaster impacts. An integrated approach towards DRM is also important in view of reducing climate-related risks. For instance, in systems where flash floods regularly take place, forest management or other land use management systems can play a huge role by reducing the intensity and speed of floods, and also potentially altering groundwater recharge (i.e. droughts).

Various organizations have adopted the nexus approach as a possible new paradigm to deal with complex and related environmental issues such as sustainable development, climate change adaptation and disaster risk reduction. UNECE[37] and the Food and Agriculture Organization of the United Nations (FAO)[38] have developed task forces to develop and promote nexus concepts further. Next to this, the Water, Energy & Food Security Resource Platform[39] is an independent information and facilitating platform funded by the German Federal Ministry of Economic Cooperation and Development and the European Union. Organizations like the Stockholm Environment Institute (SEI), the Stockholm International Water Institute (SIWI) and GWP are all contributing to further developing this nexus approach.

[37] More information available on the UNECE Task Force on the Water-Food-Energy-Ecosystems Nexus from https://www.unece.org/env/water/task_force_nexus.html

[38] More information available on the FAO Water–energy–food nexus from http://www.fao.org/land-water/water/watergovernance/waterfoodenergynexus/en/

[39] More information available from http://www.water-energy-food.org

5. Responsibilities and stakeholders

Boundaries in transboundary systems exist not just between countries. In federal systems, for instance, transboundary issues between administrative authorities may also occur and complicate matters. Moreover, failure to cooperate between these different administrative levels within a country, such as the community level with the provincial level, can have severe impacts. Thus, transboundary issues described in this guide can also be relevant for lower governance levels within countries.

5.1 Responsible institutions

Disaster risk management involves a variety of disciplines, institutions and stakeholders that are active at different levels in time (sequential interventions) but also at different scales (transboundary actors like basin-wide institutions, national actors like ministries and water boards, and local actors like alarm and rescue services, but also municipalities). Institutions dealing with disaster risk reduction generally focus on response and recovery, while institutions dealing with water management in general focus on prevention and preparedness, especially on the topic of floods and to a lesser extent on droughts. As a result, there are often less connections between these institutions than would be desirable. In order to successfully implement this guide, cooperation efforts are required between the relevant institutions. Table 2 shows examples of the different institutions dealing with DRR and water management for the different categories of organization. A comprehensive mapping of these actors and layers is needed to understand the specific mandate of each.

Table 2. Organizations typically involved in disaster risk reduction (DRR) and water management

Category	DRR	Water management
Institutions with primary responsibility	Ministry of Interior, National Disaster Management Authority, Federal Emergency Management Agency, or Ministry of Disaster Management and Relief	Ministry of Water Management, Environment, Agriculture and/or Natural Resources
Fully dedicated institutions with specific responsibilities	Meteorological services, Civil Defense, seismic research centres, search and rescue teams, fire departments, the National Red Cross/Crescent Societies	River Basin Organizations (RBOs), meteorological services, hydrological research centres and services, water boards
Sectoral ministries and local governments that have a role in integrating DRR and/or water management into development planning	Agriculture, environment, education, urban development, water, transport, gender/women's affairs/social affairs. Municipalities. In some countries, almost all government ministries may have an existing or potential role in DRR	Agriculture, industry, environment, education, urban development, transport, gender/women's affairs/social affairs. Municipalities. In some countries, several government ministries may have an existing or potential role in water management. River basin commissions
Private sector and civil society organizations (CSOs)	Insurance companies, business associations, including international NGOs, community-based organizations and women's organizations	Water Users Associations (WUAs), insurance companies, business associations, including international NGOs, community-based organizations and women's organizations

Based on Global Facility for Disaster Reduction and Recovery (GFDDR, 2017)

5.2 River basin organizations/joint bodies

Developing formalized communication between parties through, for example, joint bodies provides a means for solving possible water conflicts and for negotiating water allocations, thereby removing the need to rely entirely on inflexible rules on resource sharing. Joint bodies with a wide scope, competence and jurisdiction are hugely important for making transboundary agreements "disaster risk proof". Joint bodies, such as river basin commissions, should be responsible for the development of joint or coordinated disaster risk management strategies for transboundary basins and for following up on their implementation while evaluating their effectiveness. The bodies therefore need to have the capacity and means to effectively undertake these tasks. Furthermore, conflict resolution mechanisms such as compulsory fact-finding, conciliation, negotiation, inquiry or arbitration can help solve conflicts between concerned parties.

Many transboundary waters are, however, not covered by agreements between the riparian states and do not have the joint institutional structures in charge of their joint management and cooperation. Notably, more than half of the world's 276 international river basins, plus transboundary aquifer systems, lack any form of cooperative management framework. Even where joint institutions exist, the growing pressures on water resources—coupled with the impacts of climate change—amplify the challenges in implementing existing agreements and achieving progress in transboundary water cooperation, thereby calling for strengthened governance frameworks so as to build the required capacity to respond. Unfortunately, many river basin organizations (RBOs) lack the mandate to deal with flood or drought issues. In some cases, economic and technological developments, regional integration, the emergence of new stakeholders or other factors of evolving context require the updating of existing agreements and the strengthening of joint institutions.

Box 4. Technical cooperation on shipping in the Scheldt River

The current borders and agreements between many countries are often based on past conflicts. Cooperation between countries is nevertheless often essential for economic growth and for the population's livelihood. Following the Belgian war of independence of 1830, Belgium received the right of corridor through parts of the Netherlands, which is essential for commerce in Belgium. Some of these corridors are waterways, like the Scheldt River, an important waterway for Belgium. The Western Scheldt Estuary in the Netherlands is important for flood defense and for nature. Changes to the river, like dredging for shipping, are subject to national and international (EU) law.

A bilateral commission between Flanders and the Netherlands was established as a technical committee to inform each country of changes to legislation and the water system, and to the models that evaluate changes. The Flemish-Netherlands Scheldt Commission (VNSC) aims to protect the Netherlands and Flanders from flooding, both from the sea and upstream areas, as well as to maintain accessibility of the four harbours in the region (Antwerp, Ghent, Flushing/Terneuzen and Zeebrugge), to develop a healthy, dynamic and natural ecosystem in the Scheldt Estuary, and to cooperate with all stakeholders. The commission cooperates with the International Scheldt Commission and the Committee for Nautical Safety in Scheldemond, among others.

Sources: http://www.vnsc.eu; http://www.isc-cie.org; http://www.vts-scheldt.net

Box 5. How Lake Titicaca Authority was established after major floods

Lake Titicaca, the principal component of the TDPS (Titicaca, Desaguadero, Poopó and Salar de Coipasa, a closed basin), is located in the Altiplano region and shared between Peru and Bolivia at 3810 metres above sea level, with 8400 km^2 of surface area and 930 km^3 of freshwater. Lake Titicaca is the highest navigable lake in the world, one of twenty oldest lakes and recognized as one of the world's great lakes (PDGB, 1993). In 1997 Lake Titicaca and its watershed were included in the list of wetlands of global importance of the Ramsar Convention. The lake is a source of water and hydrobiological resources for the people living along the shores of the lake. Most of the population is extremely poor and thus the most vulnerable to the impacts of climate change and pollution caused by discharges of wastewater without treatment generated by the cities bordering the lake. The predominant activities of the local people are based on agriculture, commerce and tourism, comprising small, economic family units. (MINAM, 2013).

The TDPS system will be negatively affected by temperature variations, causing floods, droughts, greater erosion of soils, changes to land use and biodiversity, and the migration of some species, among other impacts (Bradley *et al.,* 2006).

Floods and droughts are extreme events that affect the TDPS system. A drought episode around 1000 AC was devastating for the Tiwanaku civilization. (Binford *et al.,* 1997). The intense rains caused an increase in the level of Lake Titicaca, flooding thousands of hectares (48,000 in 1986) mainly at the mouths of the Ramis and Ilave rivers in Peru, endangering the city of Oruro in Bolivia (PDGB, 1993) with an estimated US$ 125 million (1985/86) of quantifiable losses, while prolonged droughts, which are more frequent extreme events, caused losses calculated at US$ 216.5 million (droughts of 1982/83 and 1989/90) (PDGB, 1993). As a result of these adverse impacts, the governments of Peru and Bolivia created a sub-commission for the development of the Lake Titicaca Integration Zone. In 1991 this sub-commission launched a project to regulate the waters of the lake and developed the Binational Global Master Plan (PDGB) to create the Lake Titicaca Integration Zone with support from the European Union. The PDGB was approved in November 1995 (ALT, 2017).

In 1996, by agreement between Peru and Bolivia, the Binational Lake Authority created Titicaca-ALT, an entity of international public law with full autonomy in technical, administrative, economic and financial matters. Functionally and politically the ALT operates under the Ministries of Foreign Relations of Peru and Bolivia. Its main function is to manage the Master Plan (ALT, 2017). To reach the assigned objectives, the ALT has structured management into four areas: i) disaster risk management, adaptation to climate change and environmental management; ii) water resources management; iii) management of hydro biological resources; and iv) improvement of the Master Plan and Knowledge Management (ALT, 2015).

The ALT has strengthened the relations between Peru and Bolivia by: i) promoting the development of transboundary areas with the participation of specialists and professionals from both countries; ii) working on projects and activities that are financed equitably; iii) harmonizing actions with public and private organizations; and iv) developing projects at pilot level with characteristics that can be replicated in other areas of the TDPS and are scalable at real size.

The existing joint commissions and other joint bodies for transboundary water cooperation differ from one another in terms of the scope of application, competence, functions, powers and organizational structure. Nevertheless, the principles of organization and activities of joint bodies have been developed to increase their efficiency and to contribute towards reaching a mature level of cooperation between the riparian States.[40] Creating special (technical) working groups under a joint body are an important mechanism in developing joint strategies and programmes on disaster risk management, among other things.

5.3 The role of cities

Cities constitute more than 50 per cent of the world's population and account for 75 per cent of global economic activity. Cities are at risk from natural hazards owing to the vulnerability of their infrastructure and built assets, and because of the socioeconomic conditions of their residents and the absence of capacities at institutional settings. In addition, cities are highly prone to the impacts of climate change and environmental degradation. Consequently, cities and local governments are important stakeholders in DRR and CCA. Urbanization is expected to continue over the coming decades, particularly in Africa and Asia where coping capacities to disasters are limited. Local governments often cannot keep up with this rapid growth, and resources and amenities can barely cope with the increased demand. One consequence is that in every major disaster, the capacity of emergency services is overstretched, whether it occurs in developed countries (for example in New Orleans after Katrina or Houston after Harvey) or in less developed countries. Developing countries are, however, frequently impacted by flash floods, landslides and similar small scale disasters that puts a strain on emergency services.

Current flaws in city management relate to an optic of short-term development with regard to the rapid expansion of urban areas, lack of maintenance and control of existing infrastructure, limited enforcement of regulations, and silo-based sectoral approaches to new and innovative entrepreneurship. Early identification and strategic planning in support of the implementation of short-term no-regret interventions and long-term adaptive strategies are promising pathways to the timely adaptation of urban development for a more sustainable future vision. Special attention should also be afforded to the vulnerable groups in society such as the poor, women, children and the elderly, as they are often disproportionately impacted by climate change. In addition, in Africa, Asia, Latin America and the Caribbean a large proportion of urban residents live in informal settlements requiring specific risk reduction and resilience-building actions.

In urban planning, a preventive approach is needed that develops measures to prevent disasters from happening or measures to increase the resilience to cope with potentially disastrous events. This is based on risk-informed planning by mainstreaming risk reduction and resilience-building into urban plans, such as flood-risk management plans. Such preventive approaches show a return on their investment. As the incidence and severity of extreme events are expected to intensify, investment in prevention is becoming increasingly advantageous. For example, ways to increase resilience to flood risks can be achieved by developing urban drainage solutions that are integrated within urban infrastructure design so that safe flooding spaces are provided and the city acts as a 'sponge', limiting surges and releasing rainwater as a resource. It is therefore essential to plan vital infrastructure to enable a rapid recovery from disaster.

Urban centres depend on rural areas to sustain future growth in their demand for goods and services, as well as for ecosystem services, which can mitigate water-related risks. Rural areas in turn rely on urban centres for access to markets, goods and services. It is therefore crucial to understand the interdependencies between rural and urban areas in terms of water, as well as in

[40] More information available from https://www.unece.org/index.php?id=48658

such sectors as agriculture, energy, environment, biodiversity and the economy.

Ecosystem-based solutions are widely supported and embraced as these interventions are generally more cost-effective than traditionally engineered ones. Ecosystems also provide for

Box 6. Cities working together to protect the Mississippi River

The Mississippi River, America's largest navigable waterway, is under threat from climate change. Up and down the river, cities are collaborating to protect this vital resource for their citizens and industry. The Mississippi River winds through ten states across the US heartland. It acts as a vital source of drinking water for more than 20 million people. It is a major freight transport route, a natural habitat, and the vital water source for one of the world's most productive agricultural regions. The river is central to many million livelihoods and fundamental to the biggest economy on the planet.

When the Mississippi River is in trouble, the costs are huge. In August 2016 for example, over US$10 billion of damage was wrought around the Baton Rouge area of Louisiana owing to backwater collected from torrential rainfall. Since 2005, the Mississippi River Valley has seen record floods, major droughts, Hurricane Katrina and Hurricane Isaac. Disasters have become persistent and systemic, and as climate change worsens, the costs will only increase.

To manage the river and the risks that come with it, communities in the region are working together under the banner of the Mississippi River Cities & Towns Initiative (MRCTI) (www.mrcti.org), an association of 80 Mississippi River Mayors from across all ten states bordering the river. The Mississippi River Cities and Towns Initiative (MRCTI) addresses matters of concern, including:

- River water quality and habitat restoration.
- State coordination around river management and improvement.
- More impactful water conservation measures.
- Sustainable economies.
- Celebration of the culture and history of the river.

In the summer of 2017, mayors from 18 of the river's key cities gathered in Washington DC to press Members of Congress and White House officials on the need to maintain and restore the infrastructure that manages America's largest waterway. Their infrastructure proposal has the support of several businesses operating along the Mississippi River, as well as widespread community buy-in. It is calling for investments totalling US$7.93 billion to restore the river's floodplains and ecosystems and modernize its lock system.

Aware of the role of natural infrastructure in managing flood risk, the cities' plans include options to add natural green space to reduce the costs of flood damage. For example, Davenport has adapted to flooding by creating a riverfront park, giving the river room to move and limiting the impact of flooding.

The full infrastructure proposal aims to sustain critical ecological assets, generate $24 billion in economic activity, create 100,000 new jobs, support eight sectors of industry, and mitigate hundreds of millions of dollars in disaster impacts.

This collaborative proposal, which is tailored to the needs and strengths of the region, shows how effective cities and towns can be when tackling water challenges together at the water basin level.

Source: http://www.cdp.net/en/research/global-reports/cities-infographic-2017/cities-in-action better living conditions and the improved well-being of inhabitants. In this regard, Inclusive Green Growth is an important concept for city development as it is both efficient and affordable and values ecosystem services.[41]

Medium and small sized cities are an important focus as they are among the fastest growing types of city. Increasing the resilience of cities engages social structures, leadership and community awareness, as well as preparedness in developing infrastructure in a comprehensive and integrated approach. Consequently, integrating adaptation into urban redevelopment programmes requires continuous learning and action. To effect deliberate and strategic change, and to accelerate the uptake of best practices, cities increasingly need to engage in city to city knowledge networks so as to learn from other cities.

5.4 Gender issues

Women experience unequal access to resources and decision-making processes, as well as limited mobility in rural areas. Moreover, women and girls have higher levels of mortality and morbidity in situations of disaster. Gender-based economic inequalities mean that women, and female-headed households in particular, are at a higher risk of poverty and more likely to live in inadequate housing in urban and rural areas of low land value that are particularly vulnerable to the impact of climate-related events such as floods, storms, avalanches, earthquakes, landslides and other hazards. Yet, women can (and do) play a critical role in response to risk management and climate change due to their local knowledge of and leadership in, for example, sustainable resource management and/or leading sustainable practices at the household and community level. At the local level, women's inclusion at the leadership level has led to improved outcomes of projects and policies. On the contrary, if policies or projects are implemented without women's participation it can increase existing inequalities and decrease effectiveness.

To take gender issues into account in DRM, three key general principles should be included:

- Equality and non-discrimination
- Participation and empowerment
- Accountability and access to justice

Because of the significant gender differences in use, access and management of water it is recommended to encourage gender-sensitive frameworks in developing policies to address climate change and disaster risks, taking into account social, economic and environmental vulnerabilities. This also entails investing in empowerment of women and promoting a balanced participation of men and women in policy and strategy development, including in governance positions like water management committees (CEDAW, 2018).

5.5 Poverty and inequality

It is generally the poor who tend to suffer the most from disasters. Between 1975–2000, the poor comprised 68 per cent of mortalities from disasters (UNISDR, 2008). Impoverished people are more likely to live in hazard exposed areas and are less able to invest in risk-reducing measures. The lack of access to insurance and social protection means that people in poverty are often forced to use their already limited assets to buffer disaster losses, driving them further into poverty. A key factor in underprivileged areas is the low quality and insecure housing, which in turn limits access to basic services such as health care, public transport, communications, and infrastructure such as water, sanitation, drainage and roads. Poverty is therefore both a cause and consequence of disaster risk with drought being the hazard most closely associated with poverty.

[41] More information available from: http://www.oecd.org/greengrowth/futurewewant.htm

Moreover, climate change and exposure to natural hazards threaten to derail international efforts to eradicate poverty by 2030.

While absolute losses tend to be higher among wealthier groups, the relative impact of disasters on low income households is far greater. For instance, Hurricane Mitch in 1998 destroyed over a quarter of household possessions, tools or animals of the wealthiest 20 per cent of households but only a tenth in the case of the poorest 20 per cent. However, the poorest group lost nearly 18 per cent of their pre-Mitch asset value and 40 per cent of their total crop value, compared to just 3 per cent and 25 per cent respectively for the wealthiest group (UNISDR, 2018).

5.6 Consultation and participation

Stakeholder participation is crucial in all the steps in the development and implementation of disaster risk management strategies and measures. Every stakeholder should have access to the decision-making process at all stages of the risk assessment framework. From risk assessment to planning and the selection of priority risk reduction measures, the knowledge, capacity and viewpoints of everyone involved are crucial to ensuring sound, effective and sustainable adaptation. Moreover, stakeholders are part of the solution, including utilities managers who ensure that the water supply and sewerage services continue to function under changing climate conditions. Also, measures at the community level can only be effective if the communities have played a part in designing (including risk assessment) and implementing the measures.

5.6.1 Stakeholder mapping

The different actors have various instruments through which DRR can be mainstreamed, each with different potential and scope. Analysis of these different instruments is required so as to identify the ones with the greatest potential with respect to the pursued objectives. Furthermore, decisions and actions are effective only if they are made with the right knowledge of the environment, i.e. who to target, when, at which scale, and so on. This task is strongly linked to the identification and development of measures for water-related disaster risk reduction:

- The characterization of the environment will determine the possible frame for these measures, as well as where to integrate them, for instance, in the basin plan, a national strategy, a local project.
- Stakeholder engagement will identify which actor can and should (for greater efficiency) implement a specific measure, and which actor is best suited given its influence, strengths, position, and so on.

The following steps are recommended in order to come to an overall analysis of the relevant institutions and stakeholders:

- Determine the scope of the intended intervention, pursued objectives, and so on.
- Map the stakeholders that have responsibilities in DRR.
    - The specific responsibilities of each stakeholder have to be precisely identified. These responsibilities vary between institutions: from planning to implementation responsibilities and from regional to local scope.
    - Given the transversal nature of DRR, a number of stakeholders have only partial responsibilities for DRR, typically, stakeholders active in the field of water management, climate change adaptation and hydro-meteorology (see table 2). The role, mandate, responsibilities of these stakeholders regarding DRR should not be neglected as the interfaces can be significant.

    - The existing mechanisms for cooperation, coordination and alignment between the previously identified stakeholders have to be determined, as well as the limitations of the existing (or non-existing) mechanisms and the suggestions to improve them.
- Identify the different policy and legal instruments for DRM, which exist at different levels, and assess their effectiveness as these instruments are potential entry points for mainstreaming DRM.
    - In a transboundary context, these instruments can exist at different levels. Typically, the following levels should be screened:
        - River basin organizations/joint bodies: at this level a number of instruments might exist for river basin management planning. It can consist of basin wide sectoral strategies and/or an overall basin plan. Also, EIA and SEA can be performed as described under the Espoo Convention.
        - Flood Risk Management Plans and Drought Management Plans are key instruments at both the national and transboundary level.
        - National level: at this level instruments like EIA/SEA and IWRM approaches will need to be reviewed along with other approaches that link to related sectors like agriculture, energy, industry, land use and ecosystems.
    - The instruments will then have to be analysed in terms of:
        - Suitability. Are they representing good entry points for DRM measures?
        - Performance. Under their existing form, are they efficient for DRM?
        - Completeness. Under their existing form, is any aspect missing in order to achieve DRM?
        - Financial and human resources. Are the instruments properly equipped/funded with resources?

5.6.2 Stakeholder involvement

Increasing access to information, public awareness and public participation in decision-making sets the foundation for the development and implementation of policies related to disaster risk. Focusing on these aims will help build the political commitment and capacity needed to understand and address the causes and impacts of climate change, as well as approaches to mitigate such changes.

Public participation is a generally accepted approach in water management, but its implementation it still difficult. One important problem is the lack of clarity about the role of stakeholder involvement. Stakeholders often doubt whether their input can make a difference, which is critical if people are to be motivated to participate. Moreover, the existing governance style is often not participatory and it would take a considerable effort to move towards a more collaborative approach. In many cases, authorities lack experience with multiparty approaches, and they rely heavily on technical expertise and are not willing to change for fear of losing control, or they believe that broad participation could threaten the confidentiality of proceedings.

Consequently, implementing public participation generally requires political, institutional and cultural change. Occasionally opportunities for truly participatory approaches may arise at the local level or in specific policy processes, an influential politician may for instance favour public participation, or there may be a public controversy that cannot be resolved without the involvement of the public. Provided these processes are well organized, they can increase positive experiences with and support for public participation.

When stakeholders get a better understanding of the management issues at stake and get to know and appreciate each other's perspectives, possibilities for win-win solutions and solutions that the authorities had not previously considered begin to open up. Often, the participatory process results in clearly identifiable improvements for the stakeholders and for the environment.

Important preconditions for public participation are to clearly define the aims and ambition of water managers and authorities, as well as ways that the output of the participatory process will be incorporated into management and policy processes. While participatory methods may succeed in providing the informed views of certain citizens and in producing recommendations that can contribute to the quality of the decision-making, the process has to also allow for the inclusion of views and interests of these groups in the decision-making and policy processes, which determine the scope and outcomes of water management (UNECE, 2009*a*). In the consultation and participation process, care should be taken to ensure the participation of representatives of all the riparian countries so as to create a common understanding and improve decision-making.

5.6.3 Capacity development

Capacity development enables people to be better prepared for various situations and to better cope with the situation they may find themselves in. People often have to save themselves and their (remote or close) neighbours in emergency situations. Saving people can often be dangerous and the public at large often uses improvised methods to save other people. However, involving communities and organizing and training people at all levels (international, national, local) before a disaster strikes can reduce the number of fatalities. The goal of developing capacities is to effectively enable communities to lead, manage, achieve and account for their own security. This is essential, as: i) disaster risk will only be effectively reduced if there is strong national and local ownership/capacity; and ii) an effective emergency response relies on the appropriateness and timeliness of (inter)national and local interventions. Capacity development is therefore an indispensable part of DRR planning and programming. In this regard, a Global Capacity Development Strategy is being developed under the Sendai Framework for Disaster Risk Reduction.[42]

[42] More information available from https://www.preventionweb.net/events/view/56922?id=56922

6. Understanding the risks and hazards

Understanding the risks of water-related events means looking at the probability and severity of certain events and the damage it will do. In general, models are used to calculate the impacts of an event, especially in flood mapping. In addition, climate change impacts are incorporated into climate change models and scenarios, which are used to project the frequency and severity of events in the near and distant future. The results are then incorporated into the effect models. Coupled with land use maps and socioeconomic data, the overall damage can be predicted. Nevertheless, climate change can drastically change hydrological circumstances. For instance, receding glacier catchments can change drastically as a result of climate change, like the receding Kaskawulsh glacier in 2016 that caused the Slims River to dry up while the meltwater was diverted over a period of only four days in a change called “river-piracy”. The water now flows into the Gulf of Alaska instead of the Bering Sea.[43]

In this chapter, the process of understanding the risks and hazards of water-related events is described in more detail. Information collection and sharing in a transboundary context will also be elaborated.

6.1 Different types of hazards

The most prominent water-related hazards are floods and droughts. Each of these hazards has its own characteristics, requiring a divergent approach. Floods can develop over a short period of time and generally last for a period of hours to days. Floods can also cause substantial damage to infrastructure and buildings. Droughts on the other hand develop over weeks or months and can last for months. The preparation time for both hazards is thus quite different, and the prediction based on hydro-meteorological information will also differ. In general, three levels of approaches towards hazards can be distinguished:

1. Operational early warning, focusing on identifying specific hazards as they are occurring (Figure 2). In the case of floods, the system should be able to respond within hours (flashfloods) to days in larger river systems. In the case of droughts, the response time is in the order of weeks. The system should be able to identify the specific areas that are threatened.
2. Hazard mapping, focusing on possible areas at risk under current conditions. This entails modelling, extrapolating the current changes in water level to areas that are flooded (including the water depth that is reached in case of a flood), or are likely to suffer from drought. This can be done for specific areas or can extend over an entire basin. The time scale used here is approximately a decade.
3. Strategic developments under climate change, including the use of scenarios to identify possible futures at basin scale level and stretching out over decades. There is a certain level of uncertainty connected to these developments, but it is important to note that future hydrologic characteristics may substantially deviate from the current ones.

[43] Refer to the news article at https://www.theguardian.com/science/2017/apr/17/receding-glacier-causes-immense-canadian-river-to-vanish-in-four-days-climate-change (accessed 14 April).

Figure 2. Main steps of the Early Warning System chain

Source: WMO, 2017

6.2 Information collection and sharing among riparian states

Disaster risk management requires collecting and assessing a wide range of information. On the one hand meteorological, hydrological and climate information is needed to assess the exposure of assets to water-related events. On the other hand, socioeconomic information is needed to determine the potential hazard as a result of these hydrologic events. This information should be collected and shared among riparian states so as to get a sense of the shared risks.

The supporting process of monitoring and assessment should principally be seen as a sequence of related activities that starts with the definition of information needs, and ends with the use of the information product. Successive activities in this monitoring cycle should be specified and designed on the basis of the required information product, as well as the preceding part of the chain.

Information needs related to disaster risk management and climate change adaptation, as stated earlier, not only relate to meteorological, hydrological and climate prediction but also include inter alia geographic and socioeconomic information (for example, from national census data, development plans, and so on). The exact information required depends on the type of disaster. In drought situations for instance, water quality may become a limiting factor for irrigation or drinking water. The data must be available in order to develop adaptation measures at a scale ranging from local to national and to transboundary levels. Where such data are not available and would take a long time to generate (as is the case in much of the lesser industrialized world) robust approaches for understanding and guiding adaptation in data limited environments are essential. The design of a monitoring programme includes the selection of parameters, locations, sampling frequencies and field measurements, and also laboratory analyses to monitor water quality. The parameters, type of samples, sampling frequency and station location must be chosen carefully with respect to information needs. The data needed for impacts modelling and subsequent vulnerability assessment at the national, international and river basin levels include hydrological, meteorological, morphological and water quality characteristics. Statistical analysis of the previous data series, as well as statistics on diseases caused by water factors, taking into consideration age, gender, local geographical conditions, and so on, is also essential (UNECE, 2006).

To support effective cooperation in climate adaptation and disaster risk reduction at the transboundary basin level, the development of joint monitoring and joint information systems (such as databases or GIS systems) is recommended. Such systems should be based on an agreement regarding the information to be shared and the country responsible for producing the information. Existing systems should be adapted to include disaster risk and climate change issues, and where they exist, joint bodies should be responsible for this.

If a joint information system is not feasible, regular and also operational data and information exchange between different countries, bodies and sectors is needed. This includes an exchange of information on risk management and adaptation plans and measures to enable riparian countries to harmonize their activities, and the exchange of data permitting the improvement of climate and hydrological prediction models. A data comparability procedure has to be established between countries adopting different methods of data collection, different methods of data surveying, instruments, procedures, and so on.

Data should also be made publicly available, except in cases where disclosure to the public might damage confidentiality provided for under national law in terms of international relations, national defense or public security, the course of justice, the confidentiality of commercial and industrial information (where such confidentiality is protected by law to protect a legitimate economic interest), intellectual property rights, and so on. In such cases, data should be processed so that it cannot be used for purposes other than risk assessment and/or climate change adaptation.

Information collection and sharing among riparian states for flood risk analysis depends on the type of impact assessment and/or risk analysis chosen. This determines which indicators will be collected together. For instance, along rivers, information on precipitation (measured, expected) and river water levels is crucial for countries downstream. The level of detail will determine the necessary effort. If GIS is used, data as provided by the riparian countries will have to be consistent. Map systems have to be aligned and often a common reference point for the maps in the study has to be chosen.

Box 7. Flood management in the Lower Mekong Basin

In the Lower Mekong Basin, the Mekong River Commission (MRC) assessed the current and future flood risk in a number of flood prone pilot areas, taking into account future climate scenarios. The developed methodology integrated social and economic vulnerabilities to facilitate the formulation, prioritization and cost justification of the adaptation measures. The social vulnerability assessment comprised a risk matrix methodology that involved extensive community consultation, household surveys and analysis. The economic vulnerability for the moderate climate change scenario projection to 2030 was based on annual average damage analysis for the three sectors of agriculture, housing and infrastructure.

The MRC developed and operates a regional flood forecasting system for the Lower Mekong Basin for current flood risks. Being transboundary, this system relies largely on the collaboration between countries in terms of data sharing for its overall performance on the one hand, and on the benefits for the four countries in different dimensions on the other, depending on the specificities of the national contexts (forecast per se, forecast benchmark, methodological support, and so on). The system uses satellite estimates of rainfall, which are corrected using ground truth stations, provided that countries send the data in time and that they are good quality. These estimates are then processed in a modelling platform (hydrological, hydrodynamic and transfer models) to generate water level forecasts for 22 stations along the Mekong main stream. The forecast is issued daily, with a 5-day range forecast, and it is disseminated through different channels (website, bulletin, social media, fax, and so on) to a variety of actors. The response mechanisms to potential alarms are arranged at the national levels.

Hotspot areas were identified based on flood simulation modelling and later confirmed by field visits. Future projected climates for the Lower Mekong Basin were selected and a 'change factor' approach was adopted to project current climate conditions from a selected baseline (1986–2005) into the future (2030). Daily run-off and daily streamflow sequences were generated via hydrological modelling as well as possible future flood behaviour. The impact of climate change on flood behaviour (the distribution of peak annual flood discharges and water levels) was assessed by comparing existing flood behavior with flood behaviour under climate change.

Existing flood behaviour was determined using data on the behaviour of and damage caused by floods in the past. The 2011 flood was selected and designated as 'existing' flood for the hotspot areas in Cambodia, Lao PDR and Viet Nam. In Thailand, the 1994 flood was selected as the designated 'existing' flood given that it had considerably larger impacts in the Thai hotspot areas than the 2011 flood.

Flood behaviour (and damage) under the 'existing' flood was surveyed during community surveys. Hydrodynamic models were used to provide additional information on 'existing' flood behaviour. The 'climate change-induced flood behaviour' of the pilot adaptation studies, however, does not represent 'future' flood behaviour. Rather, it represents the impact of climate change on 'existing' flood behaviour, as defined by 'existing' upstream catchment conditions and 'existing' floodplain developments.

Assessing the vulnerability of community's socioeconomic systems to climate change consisted of the following methodology: i) determining the scope of the adaptation planning exercise (in this case, the strategic socioeconomic systems and assets at risk of flooding in the hotspot areas); ii) assessing the vulnerability of the 'existing' socioeconomic fabric of the hotspot areas to 'existing' flooding behaviour, i.e. the 'existing vulnerability'; and eventually iii) assessing the possible impact of climate change on existing flood behaviour and the associated effects on existing vulnerability.

The impact of flooding on the socioeconomic systems and assets of hotspot areas depends on the 'exposure' of these areas to flooding and the 'sensitivity' of the systems and assets to the adverse impacts of this flooding. The methodology provides a matrix to assist in determining the level of 'impact', which can vary in five steps from 'very low' to 'very high'. The level of impact is to be determined for each identified significant adverse impact, e.g. ill-health and disruption to schooling.

More information on MRC Flood Management & Mitigation Programme is available from http://www.mrcmekong.org/about-mrc/completion-of-strategic-cycle-2011-2015/flood-management-and-mitigation-programme/

Box 8. Sava River hydrologic and hydraulic model

Under the International Sava River Basin Commission (ISRBC), composed of the four Sava riparian countries of Bosnia and Herzegovina, Croatia, Serbia and Slovenia, a flood risk assessment methodology was developed that led to the joint identification of potential significant flood risk areas, the preparation of joint flood risk and flood hazard maps, the development and implementation of a flood risk management plan, and the design and implementation of a joint flood forecasting and flood warning system. A hydrologic and hydraulic (H&H) model was developed to support these endeavours and will be used to prepare flood inundation mapping to support the flood forecasting system. The hydrologic model product includes not only a basin-wide hydrologic model, but also hydrologic models of each major tributary and mainstream basin within the Sava River Basin. Successful development of the joint Sava River watershed H&H models will have a direct impact on international efforts to develop integrated flood hazard and risk maps, integrated data collection, and flood forecasting and warning systems, which in turn will reduce its vulnerability to natural, technological, and willful hazards.

Source:
http://www.savacommission.org/dms/docs/dokumenti/public/projects/usace/technical_documentation_sava_hms_model.pdf

6.3 Early warning systems

Early warning systems focus on allowing individuals and communities threatened by hazards to react effectively (in sufficient time and in an appropriate manner) in order to reduce the impacts and damages of the hazard. They are consequently essential in mitigating the effects of hazards. As an example, information-sharing for flood alerts is essential for both coastal areas and rivers. The disastrous 1953 coastal flood in Western Europe for instance showed the high water levels arriving in England more than six hours before they hit the French, Belgian and Dutch coasts. Unfortunately, this information did not arrive at the other side of the North Sea coast on time. This information from the UK's Met Office would have increased the sense of urgency in the Netherlands and would likely have saved lives.

To be effective and comprehensive, early warning systems should be composed of four inter-related elements:

1. Risk knowledge aimed at increasing knowledge about the risks individuals and communities face.
2. Monitoring and warning service aimed at providing the necessary information. Warning services must have a sound scientific basis for predicting and forecasting, and must be reliable enough to operate continuously to ensure accurate warnings in time to allow action. Warning services for different hazards should be coordinated where possible to gain the benefit of shared institutional, procedural and communication networks.
3. Dissemination and communication aimed at informing individuals and communities about risks and actions. Warnings should contain clear, useful information leading to proper responses to reach the individuals and communities at risk. Communication channels and tools must be identified beforehand and established at regional, national and community levels.
4. Response capability aimed at ensuring that proper response and action is undertaken by the individuals and communities at risk at the right time.

All these elements should be strongly interconnected and sustained by effective governance and institutional arrangements, including good communication strategies.

Box 9. Manual on Flood Forecasting and Warning

The *Manual on Flood Forecasting and Warning* (WMO, 2011) provides the basic knowledge and guidance to develop or to set up an appropriate and tailored national end-to-end early warning system for any situation in which a flood forecasting and warning system is required. The manual, for instance, recommends that National Hydrological Services (NHSs)—or similar institutions—are responsible to produce and issue flood warnings in line with the principle of "single source of alert". Many countries have developed their own end-to-end early warning system based either on proprietary or on open source technology. The WMO Flood Forecasting Initiative (FFI) (http://www.wmo.int/pages/prog/hwrp/FFI-index.php) is producing a series of inter-comparison tools, guidance material and an operational "community of practice" on end-to-end early warning systems for flood forecasting in order to improve the efficiency of the NHSs.

Box 10. European Flood Awareness System

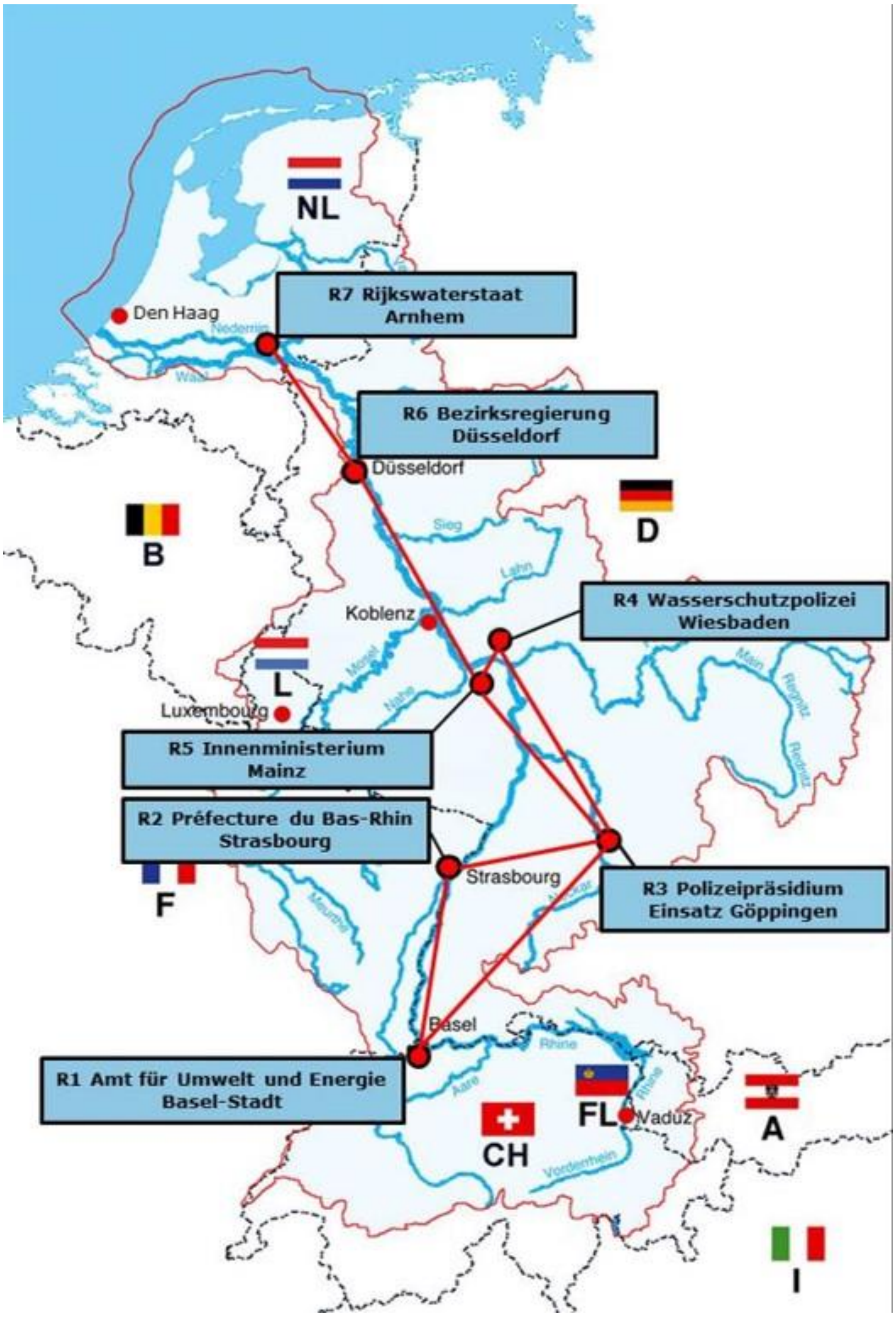
The European Flood Awareness System (EFAS) is the first operational European system that monitors and forecasts floods across Europe. It provides complementary, flood early warning information up to 10 days in advance to its partners: the National/Regional Hydrological Services and the Emergency Response and Coordination Centre (ERCC)[a] of the European Commission. The European Union has made the EFAS[b] operational for some years now. The Joint Research Centre (JRC) of the European Union is currently developing a similar global model[c]. Information on drought can be obtained from the Global Drought Observatory[d]. This system is the outcome of a Global Drought Information System mainly targeting emergency response issues.

[a] http://ec.europa.eu/echo/en/what/civil-protection/emergency-response-coordination-centre-ercc
[b] https://www.efas.eu/
[c] http://globalfloods.jrc.ec.europa.eu/
[d] http://edo.jrc.ec.europa.eu/gdo/php/index.php?id=2001

Box 11. Internationally coordinated water management in the Rhine River Basin

After the chemical accident at Sandoz in Switzerland in 1986 the International Commission for the Protection of the Rhine (ICPR) strengthened its international Warning and Alarm Plan (WAP). Despite all the preventive measures, should an accident occur, or large amounts of hazardous substances flow into the Rhine that may detrimentally impact its water quality or affect the drinking water supply along the Rhine, the model-based WAP is activated that above all warns all users downstream. Apart from the warnings, which are only issued by the International Main Alert Centres (IAC) during huge and serious water pollution events, the WAP is also increasingly used as an instrument for exchanging reliable information on unusual levels of water pollution as measured by monitoring stations along the rivers Rhine, Neckar, Main and smaller tributaries. The warnings and the information issued every year are compiled in an annual report available on the website of the ICPR (www.iksr.org/en).

The International Main Alert Centres (IAC) and information flow



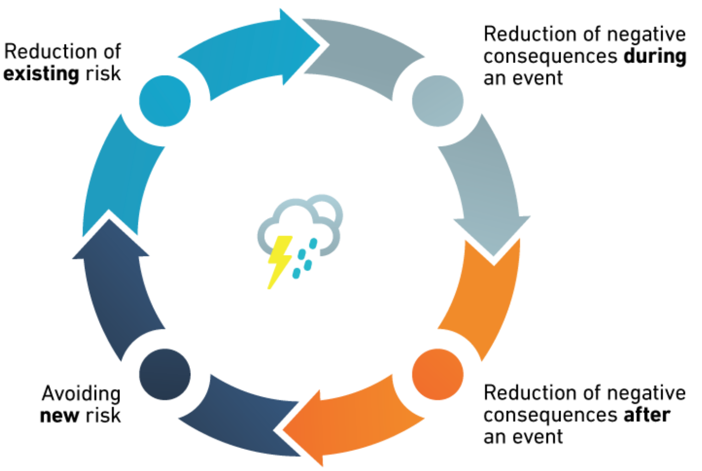
The two catastrophic flood events on the Rhine in 1993 and 1995, which caused respectively €1.4 billion and €2.6 billion of damage, were the starting point for the ICPR in dealing with quantitative issues and flood risk, and initiating operational transboundary flood risk management. Since 1998, the ICPR has implemented the Action Plan on Floods (APF) that sets out four action targets: reduce damage and water levels, and improve flood forecast and risk awareness. For the APF and the realization of measures, the riparian states have invested more than €10 billion up until 2010. Since 2007, the ICPR has established a framework for the exchange of information and for the coordinated implementation of the European Floods Directive (FD) within the International River Basin District Rhine (IRBD Rhine). In 2015, and in compliance with the FD, the ICPR published the first overriding Flood Risk Management Plan (FRMP), the measures of which are currently being implemented by the states.

In the FRMP, the riparian states have determined common principles underpinning action in the field of flood risk management within the Rhine River Basin, including among others:

- Responsibility, solidarity and proportionality between the states.
- Sustainable and integral flood risk management; the level of security to be achieved must be ecologically, economically and socially compliant.
- No 100% security, always residual risks.

These principles are translated into four overriding, general targets representing the entire flood risk management cycle (prevention, protection, preparedness, crisis management and recovery).

Overarching targets and simplified risk management cycle



Together with land settlement and human-made water works, climate change is already now resulting in modified flood patterns. Further effects of climate change on flood discharges are to be expected in the future.

The cross-border exchange and compilation of data between the countries within the Rhine basin are supported and accompanied by computer-, model- and GIS-based information systems. For the purpose of data management related to the implementation of both the European Commission Water Framework Directive and the Floods Directive (FD) within the Rhine basin, the ICPR uses the water portal WasserBLIcK (a data exchange and hosting platform) (http://www.wasserblick.net [In German]) that produces different maps for the general and specialized public.

The Rhine Atlas (http://geoportal.bafg.de/mapapps/resources/apps/ICPR_EN/index.html?lang=en) is a supra-national sensitization tool comprising aggregated flood hazard and risk maps of the countries concerned. For the main stream of the Rhine, flood depth and areas as well as objects at risk are shown for three scenarios (high, medium and low flood probability). Additional information and more detailed national maps are also available. The Rhine Atlas raises risk awareness, supports the implementation of preventive measures in flood prone areas, and represents a database for risk calculations.

Many of the measures already implemented by the states since 1998 within the APF, and those being implemented within the FRMP (such as non-structural and water retention measures among them), may be considered as win-win and no-regret measures. That means that they help reduce the negative impacts of climate change by having a positive effect on flood prevention, as well as on water quality and ecology. Besides, the riparian states are continuously exchanging information on new developments or the results of studies concerning the effects of climate change.

Furthermore, in 2015, the ICPR published a first Climate Change Adaptation Strategy for the Rhine Basin based on hydro-climatic observations and measurements during the twentieth century and scenarios for the twenty-first century. The strategy includes an assessment of the respective consequences of climate change for water quality, ecology and floods, as well as proposed actions.

In order to respect the provisions of the FD and apply the principles of subsidiarity and solidarity, the states have agreed not to increase flood risks outside their respective territories. To this end, they are effectively coordinating measures with transboundary effects.

Furthermore, with respect to climate change and the enhanced resilience of nature near water ecosystems, the ICPR promotes the coordination and implementation of measures presenting synergies between flood protection (related to FD) and ecological improvements (related to WFD). These include: giving more room to the river, the creation of retention areas, dike relocation, renaturing measures, and the restoration of habitats and ecological connections. Measures having negative environmental effects have to be reduced to a minimum. The implementation by 2020 and 2030 (retention volume of 537.3 million m^3) of these measures aims to lower water levels included in the FRMP. The FRMP also secures the surfaces needed for these and further measures (spatial planning aspects).

Flood forecasting and flood announcement contribute towards minimizing damage in case of a flood event. Therefore, national centres along the Rhine cooperate at an international level when exchanging data on discharge and precipitation, using them for flood forecasting. The quality of information and forecasting is continuously being improved.

Good crisis management planning for flood events is important in order to reduce risks during the event. The ICPR has begun to compile existing multilateral crisis management systems and its understanding of national disaster risk reduction. If necessary, this exchange of information will enable improvements in this field. This also applies to recovery measures (taken in the aftermath of a flood event).

On the topic of low water the ICPR is currently analysing past low flow events and investigating the consequences of low water on different uses of the Rhine, which could be the basis for a possible low water monitoring network or system. The International Commissions for the Protection of the Moselle and the Saar (ICPMS) are already testing such a system on the main tributary of the Rhine – the Moselle.

More information available from www.iksr.org/en

6.4 Identification and assessment of transboundary impacts of disasters

6.4.1 Basin-wide disaster risk assessment

Disaster risk assessment is an important step of disaster risk management, as made clear in Figure 1 (section 2.4). A policy guidance for conducting national disaster risk assessment and establishing a thorough understanding of risk system is provided by the UNISDR Words into Action Guideline National Disaster Risk Assessment 2017.[44] A basin-wide disaster risk assessment is needed to assess the risks as a result of potential disasters occurring in the basin. The assessment determines the nature and extent of the disaster risks, including disasters that have a transboundary nature or scope. Following the concept of disaster risk, disaster risk assessment starts with developing an understanding of the three constituents of risks (Figure 3) (APFM, 2007*b*):

- The magnitude of the *hazard* expressed in terms of frequency and severity (depth, extent, duration and relative velocities).
- The *exposure* of human activities to disaster.
- The *vulnerability* of the elements at risk.

Understanding *hazards* requires hydro-meteorological analysis, hydrologic and hydraulic simulation of surface run-offs, inundations, evaporation, water abstraction and water use, and so on. It may also require a simulation and analysis of projected conditions of land use change, future developments (e.g. urbanization, infrastructure development, etc.), and the future trends of hydro-meteorological phenomena as a result of climate variability or change. Risk maps developed for different scenarios help understand and communicate with different stakeholders.

Analysis of *exposure* requires knowledge of the existing land use and the kind of activities that are undertaken in these areas. This analysis is useful in order to consider the regulatory mechanism as one possible alternative for risk reduction. It is also important to assess the exposures based on the planned and contemplated future land uses.

Analysis of the *vulnerability* of the section of society exposed to a hazard will show why and to what extent they are affected. It may be attributable to social factors (poverty, livelihoods, gender, weaker social groups, minority and ethnic groups) and the attributing conditions of vulnerability (physical, constitutional, motivational) of the communities. A demographic analysis based on surveys may be required for this purpose. Close involvement of the communities in these assessments along with the experts would give credence to such studies.

[44] More information available from http://www.unisdr.org/we/inform/publications/52828

Figure 3. Risk as a function of hazard, exposure and vulnerability

Source: http://www.un-spider.org/risks-and-disasters/disaster-risk-management

Disaster risk assessment helps decision makers and related stakeholders of a river basin:

- Understand (and agree on) the priority hazards in the basin that need to receive attention.
- Understand the nature and extent of risks associated with the hazards of priority.

Disaster risk assessment is important as it provides a basis on which to establish risk management objectives and to identify potential DRR measures. Given the inherent uncertainty in the location, timing, severity and impacts of hazards, the role of disaster risk assessment is to reduce the impacts of such events. This is done by bringing the best information and judgment into the assessment and using that to design appropriate strategies to lessen the disaster risks.

Depending on time, resources, data and the expertise available a basin-wide disaster risk assessment can be carried out either in a simple and qualitative way or in a more comprehensive and quantitative way (often with the use of models). The confidence among riparian countries on the results of a basin-wide disaster risk assessment however will depend not only on the methodology used but also on the data and knowledge deployed and level of agreement reached in the assessment. A distinction should be made between risk assessment of an *intensive* disaster risk (a disaster risk with low probability but high impact events such as in general earthquakes, tsunamis, large volcanic eruptions, flooding in large river basins or tropical cyclones) and an *extensive* disaster risk (a disaster risk with high probability but low impact events such as in general flash floods, storms, fires and agricultural and water-related drought). It should be noted that the latter is often not accounted for in national loss databases. Although the impact of intense (or large) events can be severe and losses high, increasing evidence suggests that the accumulated losses from small and recurrent events are significant, especially in low and middle income countries. Both types of risks should therefore be accounted for.[45]

Extreme weather events can also impact the operation of water supply, drainage and sewerage infrastructure, and the functioning of wastewater treatment plants, thereby posing threats to public health. The Guidance on Water Supply and Sanitation in Extreme Weather Events[46] was developed under the UNECE-WHO/Europe Protocol on Water and Health to highlight how adaptation policies with regards to water supply and sanitation should consider: i) the new risks from disasters; ii) how vulnerabilities can be identified; and iii) which management procedures could be applied to ensure the sustained protection of health and the proper functioning of key water and sanitation infrastructure at times of flood and drought. The Integrated Flood Management (IFM) tool on Health and Sanitation Aspects of Flood Management also provides an entry point to detailed literature and know-how on the topic (APFM, 2015).

6.4.2 General considerations in disaster risk assessment

A common risk analysis between riparian states starts with determining goals, for instance whether the study is just meant to identify hazardous areas or whether a common flood or drought risk management plan is the objective. Here, considerations on intensive and extensive risks, and future versus existing versus new risks are tabled, among other things. Once the goals have been set, a common methodology has to be established. The success of the common methodology depends on the availability of comparable information from each country and the availability of common tools.

Certain trade-offs also have to be made. In some countries a lot of the information is in the public domain while in other countries the information has to be collected or purchased. Sufficient time is needed to develop common tools and a common vocabulary. For instance, choosing the languages in which to publish and in which to communicate within the team is essential. Formal documents will often be in the formal languages of each country; borders are often both administrative and linguistic. Choosing a common language for oral communication is important in order to create a level playing field in the team. In the International Commission for the Protection of the Danube River (ICPDR) for instance, English is chosen as the common language, a language that is not native to any of the countries.

Once the results are obtained, time is needed to inform the public officials of all the countries involved so as to develop a common communication strategy. This communication strategy should take into account the issues that are important for each country. Flood and drought risk awareness varies between neighbouring countries, and impact assessments, risk mapping and risk analysis can be very confrontational. For a study to succeed all riparian states have to, for example, identify flood or drought prone areas in the same way. This may also imply that new areas are identified as flood or drought prone. To avoid surprising national policymakers, a structured communication approach is necessary.

Defining a common vocabulary and methodology is essential. Some essential concepts to reach agreement on are:

- The hazard as a physical event or human activity with the potential to result in harm to people and damage to goods and property.
- Areas at risk from flooding (inhabited flood prone areas) or droughts (water-intensive use of drought prone areas).

[45] More information available from https://www.preventionweb.net/risk/intensive-extensive-risk
[46] Available from http://www.unece.org/index.php?id=29338

- Probability of an occurrence and the methodologies to determine this probability.
- Consequences, potential damages and fatalities.
- Risks, as the combination of hazard, exposure and vulnerability.

This approach can result in a matrix to assist in determining levels of vulnerability based on assessed impacts and adaptive capacity, which can be classified from 'very low' to 'very high'.

Communicating the results is often done through maps. Maps have to be adapted to the user, meaning that common concepts can be used. Examples of mapping methods are given in Martini and Loat (2007) and in APFM (2013*a*). Hazard maps are often based on historical information and information from hydrodynamic models in river systems. Due to climate change and river engineering structures, new areas may be at risk. In risk modelling, model chains can be used. A model chain is a series of models where the output of one model serves as input for another, for instance, a climate model provides input for a hydrologic model that, combined with a land-use model, can be input for an agricultural model.

The vulnerability of strategic systems and assets of a hotspot community to extreme events depends on the impacts of these events (as discussed earlier), as well as the community's adaptive capacity or the community's ability to minimize or avoid impacts. Key elements of a community's 'adaptive capacity' are:

- Access to knowledge, both within the community (education) and to external knowledge.
- Access to technology, again both within and outside the community.
- Access to institutions, and their inherent capacities and efficiencies.
- The economy of the area of interest.

6.4.3 Steps in assessing disaster risks

The basic steps for disaster risk assessment include:

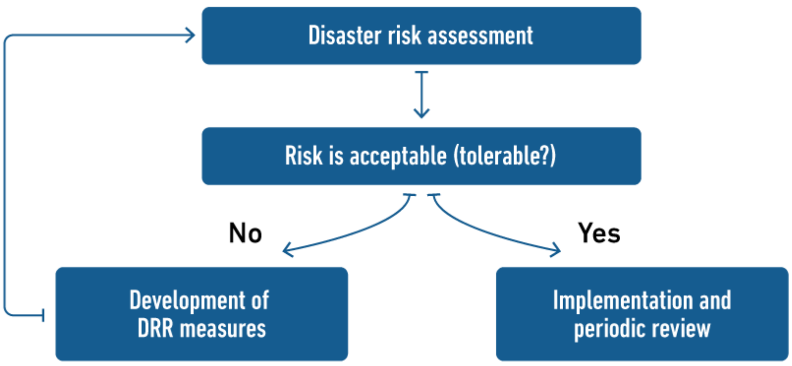
- Assess the hazards, exposure and vulnerability to hazards. This includes hazard data collection and mapping, losses and damages data collection and mapping, and exposure and vulnerability analyses. In case of future disaster risk assessment, the impacts of climate change and regional economic connection should be considered.
- Determine the priority hazards. Due to time and resource constraints for Disaster Risk Assessment (DRA), riparian countries will need to define the priority disasters among the many occurring in the basin. Prioritization can be done via workshops facilitated by information briefs prepared by an assessment team through researching previous events and conducting interviews with experts in the region. The information brief can also include 'worst-case scenarios' relating to each priority hazard.
- Evaluate the disaster risk and confidence in the results. The confidence in the results of the DRA is defined as a combination of confidences on data and information, expertise, and the level of agreement reached. A matrix can be built to facilitate the assessment of confidence on risk assessment results based on certain criteria, for example:
    - Whether data and information is sufficient and specific on site/location/community.
    - Whether knowledge on the hazards and on the assessment process is specific enough.
    - Whether agreement has been reached on the interpretation and rating of the risks.
- Evaluate disaster risk acceptability/tolerability. The acceptability or tolerability of a disaster risk is primarily assessed in consultative workshops and then presented to decision makers for final decision. Acceptability of disaster risk depends on

mutual/agreeable judgment on the likelihood of the impacts, the level of impacts, and the confidence in the assessment of the (future) disaster. Decision-making on whether further action needs to be taken or not will depend on this acceptability of risks after a measure is implemented, as shown in figure 4. Disaster risks can be broadly classified into three levels of acceptability/tolerability. Participants of consultation workshops and/or decision makers will be invited to define and/or classify the level of acceptability for each disaster risk into these three types:

- *Broadly acceptable*: risks that are acceptable or so small that no additional actions are required. They have insignificant consequences or rarely occur. The aim of risk management is to drive as many risks into this category as practicable through risk reduction measures.
- *Tolerable*: risks that can be managed by existing risk management systems. Active steps and financial management to reduce these risks are likely to already be taking place because a positive cost–benefit analysis ratio for investment is expected or because public expectation demands it. These risks should be reduced to As Low As Reasonably Practicable (ALARP).
- *Generally intolerable*: risks are too high and require further actions to lower or even eliminate the likelihood or the consequences.

The last step of this methodology focuses on identifying adaptation measures to address vulnerabilities in strategic assets and systems, prioritizing these measures, ensuring that they are robust with respect to climate change impacts, and drawing up adaptation plans to implement the selected measures. This will be described in the next chapter.

Figure 4. Linkages between disaster risk assessment and development of measures



7. Develop strategies to reduce risk

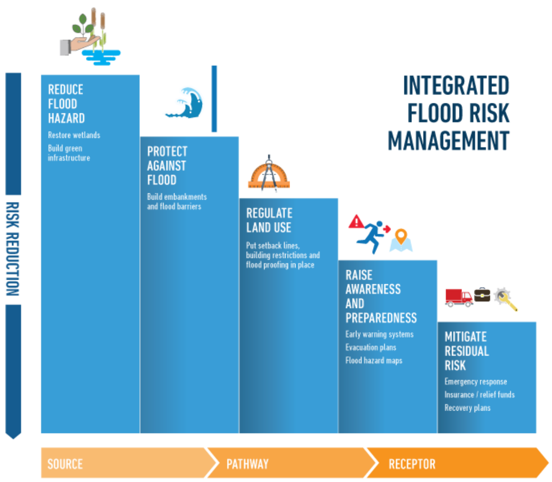
7.1 Disaster risk phases

Disaster risk management not only targets the events around disasters, it should also target the reduction of risks and the mitigation of impacts from extreme events. To this end, a cascade of phases is distinguished (see example in figure 5) (APFM, 2017), outlined by the following:

- *Prevention/mitigation*: measures and activities incorporated in regional and national development planning that reduce the probability and/or the impacts of disasters.
- *Preparedness*: measures and activities aimed at reaching an appropriate level of readiness to respond to any emergency situation that might arise, through programmes that strengthen the technical and managerial capacity of governments, organizations and communities to respond.
- *Response*: measures and activities aimed at providing immediate assistance to maintain life and improve the health of the affected population during an emergency situation. The focus in this phase is on meeting the basic needs of people until permanent and more sustainable solutions are in place.
- *Recovery*: activities aimed at restoring livelihoods and supporting infrastructure, making use of opportunities to reduce future vulnerability. The "build back better" concept fits here to ultimately enhance prevention and preparedness.

For each of the phases, specific measures should be identified and designed, as discussed in this chapter.

Figure 5. Example of an Integrated Flood Risk Management Cascade with potential integrated flood management measures and associated policy and management fields



Source: http://www.floodmanagement.info/portfolio-item/integrated-flood-risk-management-cascade/

7.1.1 Prevention and mitigation of disasters

Prevention measures are taken to reduce existing risks or prevent new risks often as a result of the negative impacts of climate change and climate variability on water resources that exacerbate existing risks. Climate change adaptation is in essence targeted at prevention and the mitigation of disasters. Prevention measures are based on risk, hazard and vulnerability maps under different scenarios. To support them, projections are needed both on a medium- and long-term basis. Prevention measures can include, for instance, the minimization or complete prevention of urban development in flood-prone areas or the development and implementation of water-efficient methodologies in water-dependent sectors (such as agriculture, industry), but also measures to improve the retention of water such as wetland restoration/protection or afforestation, which also helps prevent landslides and land degradation. Prevention measures may be targeted to long-term developments (for example, afforestation or wetland restoration/protection), to medium-term developments (for example, reduction in water use in industries and agriculture) and short-term developments (for example, population migration from flood-prone areas), but are often of a long-term nature. Where the threat of climate change makes the continuation of an economic activity impossible or extremely risky, consideration can be given to changing the activity. For example, a farmer may choose a more drought-tolerant crop or switch to varieties with lower moisture needs. Similarly, cropland may be returned to pasture or forest, or other uses may be found such as recreation, wildlife refuges or national parks (UNECE, 2009*a*).

Measures to improve resilience aim to reduce the negative impacts of hazards by enhancing the capacity of natural, economic and social systems to adapt to these impacts. Resilience is often enhanced by the diversification of activities that are less inherently vulnerable. Measures to improve resilience target long-term developments in general, including land-use planning activities. Also other measures contribute to resilience, such as switching to crops that are less water demanding or are salt-resistant. Improving resilience can also be done on a short-term horizon, for instance by operating dams and water reservoirs (surface and underground) in such a way that sufficient water is retained and stored in the wet season to balance the water needed in the dry season. Healthy ecosystems can thus increase resilience. The conservation and restoration of ecosystems should therefore be an integral part of risk management strategies.

7.1.2 Preparedness for disasters

Preparation measures aim to reduce the negative impacts of extreme events on water resources management. Such measures are based on risk maps under different scenarios. To support preparation measures, short-term weather forecasts are needed as well as seasonal forecasts. Preparation measures include early warning systems, emergency planning, awareness-raising, water storage, water demand management, and technological developments. Preparation measures are usually established to run over a long period of time, but are often only active at the operational level (UNECE, 2009*a*).

A specific preparedness tool is the people-centered early warning system. The objective of people-centered early warning systems is to empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury, loss of life, and damage to property and the environment. A complete and effective early warning system comprises four inter-related elements spanning knowledge of hazards and knowledge of vulnerabilities, through to preparedness and the capacity to respond (UNISDR, 2006).

7.1.3 Response measures

Response measures aim to alleviate the direct impacts of extreme events. To support response measures, seasonal and short-term weather forecasts are needed. Response measures include, for instance, evacuation, establishing safe drinking water and sanitation facilities inside or outside affected areas during extreme events, movement of assets out of flood zones, and so on. Response measures target the operational level (UNECE, 2009*a*).

7.1.4 Recovery measures

Recovery measures aim to restore the economic, societal and natural system after an extreme event. To support recovery measures, predictions are needed both on a seasonal and on a long term basis. Recovery measures include for instance activities for the reconstruction of infrastructure, and they operate at the tactical level both short term and long term, for example in the restoration of the electricity supply. Recovery measures also include insurance as a risk transfer mechanism. It is worth noting that recovery measures do not necessarily aim to restore the situation that existed before the extreme event. On the contrary, recovery measures can actually help reduce future vulnerabilities (e.g. by rebuilding with different types of structures or in different places, adding more redundancy, having plans in place for green solutions). Especially when the existing systems are highly vulnerable, severe damage to or destruction of the systems may be an occasion to switch to less vulnerable systems. The rebuilding of houses or industries destroyed by floods may for instance be carried out in places that are less flood-prone. The destruction of crops by severe or prolonged droughts may be an occasion to change to less drought sensitive crops or to alternative economic activities. Especially during and after response and recovery, an evaluation should be made of the prevention, resilience improvement, preparation, response and recovery measures related to the extreme event (UNECE, 2009*a*). As recovery measures can guide other actions for years or decades, and potentially increase future vulnerabilities, recovery should be carefully planned and decisions should not be made on an ad hoc or short term basis.

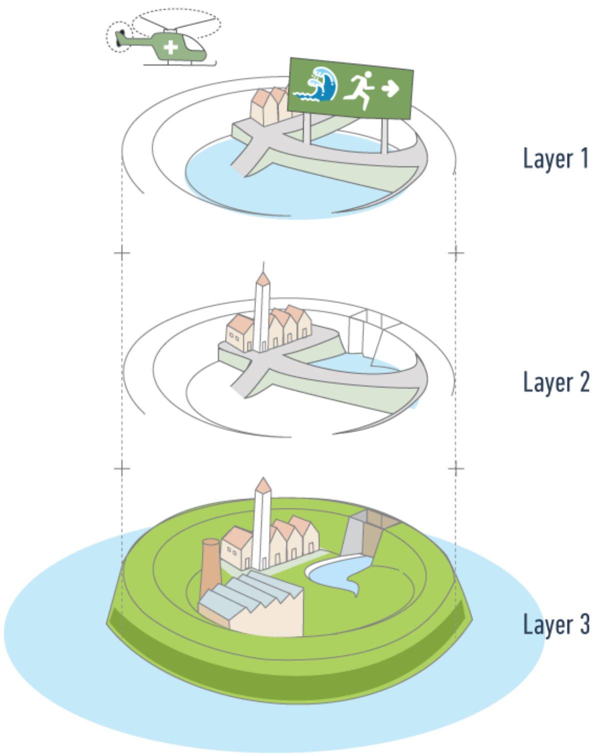
Box 12. Multilayer safety in the Netherlands[a]

The Netherlands has adopted a system of so-called multilayer safety for flooding that relates to disaster risk phases.

Layer 1 deals with measures to reduce the risk of flooding to a certain level. Measures include the construction of dikes, making room for the river, and finding solutions using nature. This layer corresponds largely to the prevention/mitigation phase.

Layer 2 deals with measures to reduce impacts. Measures include compartmentalization, waterproofing and floating buildings, evacuation routes, and building restrictions in flood prone areas. This layer corresponds largely to the preparedness phase.

Layer 3 deals with measures to improve disaster management in the case of flooding. Measures include contingency planning, evacuation planning, improving risk awareness, and the creation of shelters. This layer corresponds largely to the response phase.



Sourse: https://www.hkv.nl/upload/publication/A_comprehensive_assessment_of_multilayered_safety_in_flood_risk_management_BM.pdf

7.2 Identify measures

Once acceptability or tolerability has been determined, priority areas for risk reduction in the basin can be decided upon and disaster risk reduction measures/options can be developed. Consultation in risk assessment can be done through workshops to identify possible measures for risk reduction. Workshop participants will be asked to think broadly about possible options that may help to reduce risks. This aims to draw out potential opportunities while participants are engaged in the assessment process. The identified options will then be presented to the decision-making committee for inclusion into the framework of the DRR strategy or the DRM plan. To facilitate further decision-making, a review of the proposed options and measures and risk reduction priorities is required. This aims to provide decision makers with information regarding the anticipated level of effectiveness of the proposed options and to note whether there is any overlap or potential synergy with the ongoing disaster risk management activities. Once the DRR measures are selected they become part of a basin risk reduction project or basin disaster risk reduction plan.

The principles and strategies to reduce risks include:

(a) Avoid the construction of new risks.
(b) Address pre-existing risk.
(c) Share and spread risk.
(d) Consider residual risk.

In general, land-use planning and ecosystem rehabilitation are central measures to reduce hazards. For measures to reduce exposure and vulnerability, it is necessary to identify and reduce the underlying drivers of risks which are particularly related to poor development choices and practices (e.g. building in flood prone areas), degradation of the environment, and poverty and inequality, but also climate change. At basin level, it is essential that IWRM and DRR planning processes are integrated to ensure correct mutual tuning and adjustment.

Another issue is that economic growth often increases risks at a faster pace than climate change. For instance, an increase in population and economic growth leads to increased investments in flood prone areas. These developments result in an escalation of the consequences of flood events (Hallegatte, 2011). This means that flood defenses should be improved over time (Kind, 2014). If the measures (e.g. dike strengthening) do not keep up with increased flood risks, then policy goals are diminished. Moreover, long term funding to cover such costs decade after decade is a delicate issue even if cost–benefit analysis demonstrates this to be worthwhile. As a result, serious disasters may happen.

7.3 Different types of measures

Measures should focus on actions aimed at specific issues. They can be individual interventions or they can consist of packages of related measures. Measures should be based on generally available global or local information, like predictions of changes in hydrology combined with expert and local knowledge. The portfolio of policies and measures should also be designed on the basis of a thorough consideration of costs and benefits, and aim to ensure that measures complement and reinforce one another. Care should be taken that both structural and non-structural options are included when selecting measures. Structural measures relate to any physical construction to reduce or prevent the possible impact of hazards, or the application of engineering techniques to achieve hazard resistance and resilience in structures or systems (UNISDR, 2009). Structural measures can include engineered (hard) methods such as dams or floodways, and natural and nature-based (soft) methods such as wetland protection, upper watershed restoration or rain gardens (WWF, 2016). Non-structural measures refer to those not involving physical construction but that use instead knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness-raising, training and education (UNISDR, 2009). Mixtures of engineered and nature-based infrastructure also possible.

To be successful, any risk reduction strategy should include measures that cover all the steps of the disaster risk management cycle: prevention/mitigation, preparedness, response and recovery. Measures for prevention and mitigation should also take into account the gradual impacts of climate change. Preparedness, response and recovery measures are mainly relevant for extreme events such as floods and droughts. As there is a continuum of risk reduction measures, it is not always feasible to categorize certain measures as one specific type (see table 3) (UNECE, 2009*a*).

Box 13. Implementation of the EU Floods Directive in the Danube

In September 2007, a directive of the European Parliament and the European Council on the assessment and management of flood risks, the EU Floods Directive (FD), was adopted by the European Council. The aim of the FD is to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity.

The FD required Member States to first carry out a preliminary flood risk assessment by 2011 to identify areas at risk of flooding. For such areas they needed to draw up flood risk maps by 2013, and establish flood risk management plans focused on prevention, protection and preparedness by 2015. The FD applies to inland waters as well as all coastal waters across the entire territory of the EU. For International River Basin Districts (IRBD) such as the Rhine and Danube catchments with several Member States and also sometimes beyond the boundaries of the European Union, a single flood risk management plan is being worked out. Member States shall nonetheless coordinate their flood risk management practices in shared river basins, including with third countries, and shall in solidarity not undertake measures that would increase the flood risk in neighbouring countries. Member States shall take into consideration long term developments, including climate change, as well as sustainable land use practices in the flood risk management cycle addressed in this directive.

The FD shall be carried out in coordination with the Water Framework Directive (WFD), notably by flood risk management plans and river basin management plans being coordinated, and through coordination of the public participation procedures in the preparation of these plans.

The implementation of the FD in the Danube River Basin District was carried out under the International Commission for the Protection of the Danube River (ICPDR) Action Programme on Sustainable Flood Protection in the Danube River Basin. The countries committed themselves to developing one single international Flood Risk Management Plan or a set of flood risk management plans, making full use of existing synergies with the Danube River Basin Management Plan. A preliminary flood risk assessment (PFRA) was completed by December 2011. Subsequently, the ICPDR prepared flood risk and flood hazard maps at the level of the IRBD, including a map of hazard and flooding scenarios, a map on risk and population, a map on risk and economic activity, a map on risk and IPPC (Integrated Pollution Prevention and Control) installations, and two maps on WFD protected areas.

Source: www.icpdr.org/main/activities-projects/implementation-eu-floods-directive

Box 14. Climate change adaptation in the Dniester River Basin

The Strategic Framework for Adaptation to Climate Change in the Dniester River Basin[a], completed in 2015 by the basin countries (Republic of Moldova and Ukraine), was one of the world's first transboundary basin climate change adaptation strategies and the result of joint efforts by international experts and organizations, such as the United Nations Economic Commission for Europe (UNECE), the Organization for Security and Co-operation in Europe (OSCE), and experts and organizations from the Republic of Moldova and Ukraine with an interest in the protection and sustainable use of natural resources in the transboundary Dniester River Basin under the conditions of a changing global climate. With a population of approximately seven million people, the Dniester River Basin is an essential source of water for industry, agriculture, energy and the population centres in both countries, as well as beyond the limits of the basin itself. The Dniester River is expected to be significantly affected by climate change, leading to warmer and wetter winters and hot, dry summers, including floods and droughts.

The Strategic Framework brings together the data currently available on the present and possible future trends in climate change in the Dniester basin. It contains a set of measures; the joint and coordinated implementation of which will make it possible to timely respond to the anticipated changes. The document builds upon and complements the different national policy documents and strategies, e.g. the Climate Change Adaptation Strategy of the Republic of Moldova and the Dniester River Basin Management Plan. The framework was subsequently supplemented by an implementation plan serving to attract funding for basin-wide adaptation measures in an effective and coordinated way. The Implementation Plan[b] provides a detailed breakdown of adaptation measures with a total budget of €235 million that points to potential sources of finance and links to ongoing projects and activities in the two basin countries. Measures dealing with extreme flooding events are summarized below. They are classified as:

- **Joint** actions by countries at the basin level (transboundary cooperation required).
- **Coordinated** actions by countries in order to do a better job of protecting the interests of the basin as a whole (transboundary cooperation desirable).
- **Autonomous** harmonized actions in countries and individual sections of the basin (transboundary cooperation useful).

[a] Available from http://www.unece.org/index.php?id=45918

[b] Available from http://dniester-basin.org/wp-content/uploads/2011/05/ImpPlan_Engl_web.pdf

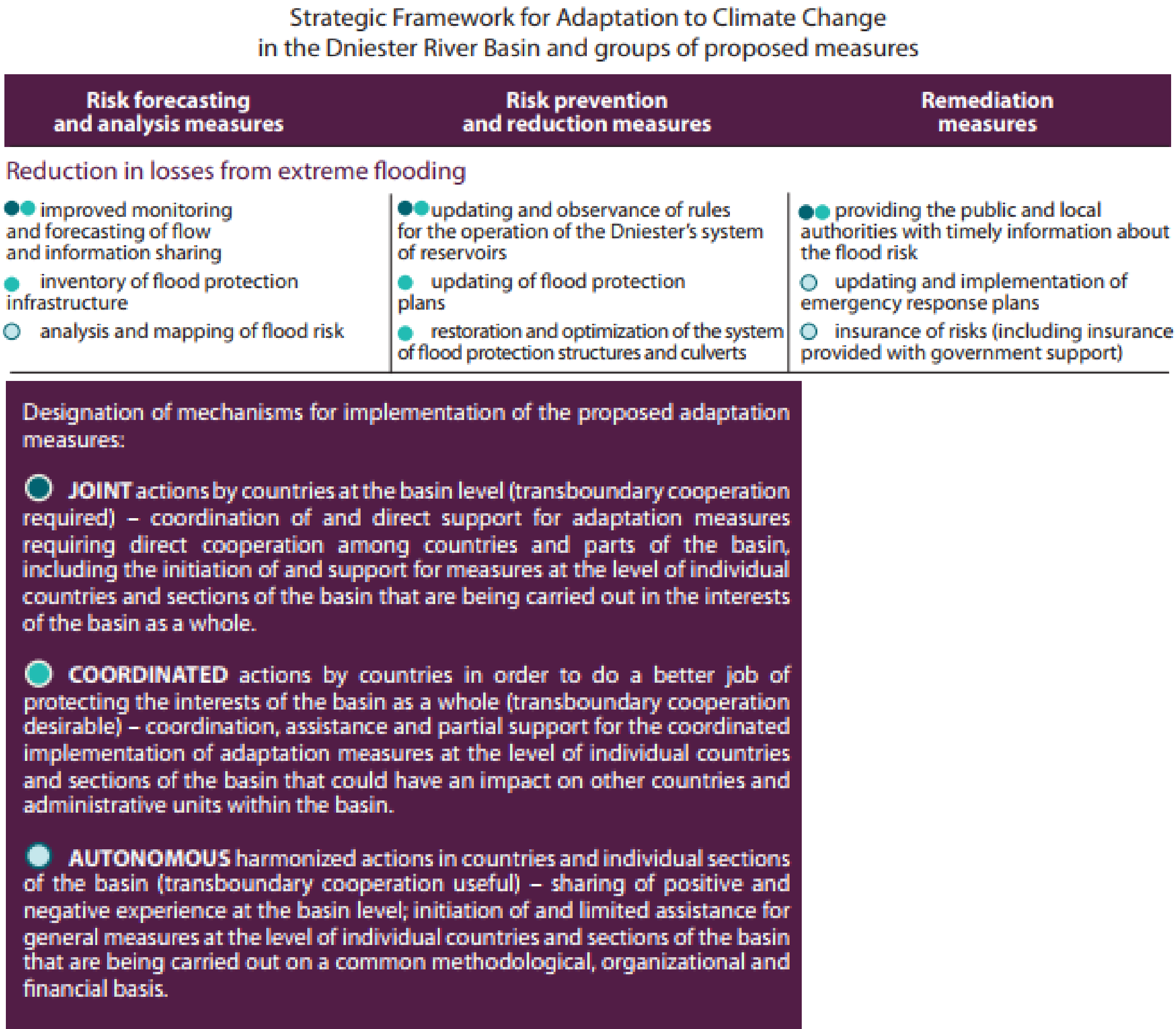


Table 3. Overview of possible risk management measures

The table provides an overview of possible risk management options. In italics are those adaptation options that are most likely to have a transboundary impact or could benefit from transboundary cooperation/ consultation. The list is non-exhaustive.

Type	Flood prone situation	Drought prone situation	Impaired water quality	Health impacts
Prevention / improving resilience	Restriction of urban development in flood risk zones. Measures aimed at maintaining dam safety, afforestation and other structural measures to avoid mudflows. Construction of dykes. Changes in operation of reservoirs and lakes. Land use management. Implementation of retention areas. Improved drainage possibilities. Structural measures (temporary dams, building resilient housing, modifying transport infrastructure). Migration of people away from high-risk areas. Improved land management, e.g. erosion control and soil protection through tree planting. Relocation of infrastructure. Protection of existing natural barriers.	Reduce need for water. Water conservation measures / effective water use (industrial and other sectors' practices and technologies, recycling / reusing wastewater). Water saving (e.g. permit systems for water users, education and awareness-raising). Land use management. Foster water efficient technologies and practices (e.g. irrigation). Enlarge the availability of water (e.g. increase of reservoir capacity). Improve the landscape water balance. Introduction or strengthening of a sustainable groundwater management strategy. Joint operation of water supply and water management networks or building new networks. Identification and evaluation of alternative strategic water resources (surface and groundwater). Identification and evaluation of alternative technological solutions (desalination; reuse of wastewater).	Prevention and cleaning up of dump sites in flood risk zones. Improved wastewater treatment. Regulation of wastewater discharge. Improved drinking water intake. Safety and effectiveness of wastewater systems. Isolation of dump sites in flood risk zones. Temporary wastewater storage facilities. Catchment protection (e.g. increasing protected areas).	Strengthen capacity for long-term preparation and planning, especially to identify, address and remedy the underlying social and environmental determinants that increase vulnerability. Use existing systems and links to general and emergency response systems. Ensure effective communication services for use by health officials. Regular vector control and vaccination programmes. Public education and awareness-raising. Measures against the heat island effect through physical modification of built environment and improved housing and building standards.

Type	Flood prone situation	Drought prone situation	Impaired water quality	Health impacts
		Increase of storage capacity (for surface and ground waters) both natural and artificial. Economic instruments like metering, pricing. Water reallocation mechanisms to highly valued uses. Reducing leakages in distribution network. Rainwater harvesting and storage.		
	Implement emergency, contingency and disaster planning. Construct new housing and infrastructure.			
Preparedness	Flood warning (incl. early warning). Emergency planning (incl. evacuation). Flash flood risks (measures taken as prevention because the warning time is too short to react). Flood hazard and risk mapping.	Development of drought management plan. Change in reservoir operation rules. Prioritization of water use. Restrictions for water abstraction for appointed uses. Emergency planning. Awareness-raising. Risk communication to the public. Training and exercise.	Restrictions to wastewater discharge and implementation of emergency water storage. Regular monitoring of drinking water.	Strengthen the mechanism for early warning and action. Improved disease / vector surveillance/ monitoring. Ensure well-equipped health stations and availability of communication and transportation facilities. Develop water safety plans.
Response	Emergency medical care. Safe drinking water distribution. Safe sanitation provision. Prioritization and type of distribution (bottled water, plastic bags, etc.).			
Recovery	Clean-up activities. *Rehabilitation options such as reconstruction of infrastructure.* Governance aspects such as legislation on inter alia insurance, a clear policy for rehabilitation, proper institutional settings, rehabilitation plans and capacities, and information collection and dissemination. Specially targeted projects: new infrastructures, better schools, hospitals, etc. All kinds of financial and economic support. Special tax regimes for investments, companies, people. Insurance. *Evaluation.*			

Source: UNECE, 2009*a*

7.4 Prioritizing measures in transboundary basins

There are various constraints—physical, technical, economic and political—in any decision-making. Societal values, perceptions of risks and the trade-offs between development and environmental preservation differ among various stakeholders, but they need to be taken into account. Economic analysis helps to select not only the optimum level of adjustment to hazards on the basis of risk-safety trade-off decisions but it can also help arrive at an optimum combination of measures for the purpose. In order to minimize subjectivity in decision-making, environmentally sensitive economic analysis can play a key role in trade-offs and conflict situations. Economic analysis provides the rationale for taking action because it provides perspectives on the scale of impact and feasibility. The expected benefits of the interventions can be evaluated along with the possible costs so as to facilitate discussion in the decision-making process. In transboundary basins, this also includes attributing benefits and costs to the respective countries. Where there is a discrepancy in benefits and costs between countries, compensation schemes can be designed. A well-functioning joint body can be instrumental in both identifying the optimal measures as well as the operating and maintenance of measures.

Cost–benefit analysis (CBA) is an economic analysis method that seems to offer a solution in selecting the best strategy, but it contains many assumptions and has certain limitations. For example, it fails to address the issues of equity. There are, for instance, many arguments about the value of ecosystems, how to appraise the future value compared with the current value, and whether one can compare welfare on the one hand with economic profit on the other. Methods are now available and used for estimating un-marketed environmental values such as the benefits of improved river water quality or the costs of losing an area of wilderness to development. Nevertheless, often the benefits and costs are not readily apparent and are beyond assessment. For example, policy issues, such as social improvements to alleviate poverty, cannot be explained solely in economic terms. The general practice to date has been to include only the direct costs and benefits, even though intangible benefits are slowly being recognized as important. A nice example of the application of CBA is given in the OECD study on the resilience to major flooding in the Seine river basin.[47] Costs should include both one-off expenditures for capital investments as well as recurrent costs that include operational costs. Apart from direct costs, there are often indirect costs (for example, in the form of an additional burden to the administrative system of the country) and external costs (linked for example to negative impacts in another sector).

Another line of approach has been to develop complementary analytical tools such as multi-criteria analysis (MCA). MCA also takes into consideration other aspects such as environmental preservation, cultural heritage, social values, and so on.[48] MCA is useful in ranking options and shortlisting a limited number of options for subsequent detailed appraisal, for example, CBA. MCA can be used by stakeholders to explore the nature of choices, determine the critical factors, discover their own preferences, and simplify the process of selecting critical options. The subjective factors in arriving at figures that best reflect social valuation are a critical issue. One obvious way in which this problem can be handled is to involve the affected people in various stages of analysis. As evaluation involves social values, it would be quite appropriate to carry out CBA/MCA in close consultation and with the participation of the public affected by a particular project. This requires effective stakeholder participation and appropriate enabling mechanisms (APFM, 2007*a*).

Next to analytical tools like MCA and CBA, general criteria to select relevant risk management

[47] More information available from https://www.oecd.org/gov/risk/Flood-risk-management-seine-river-executive-summary.pdf

[48] More information available from http://www.floodmanagement.info/portfolio-item/economic-aspects-of-integrated-flood-management/ and from http://www.floodmanagement.info/portfolio-item/conducting-flood-loss-assessment/.

options can be applied that include (WWF, 2015):

1. Will this option be effective? How effective would this measure be in achieving the overall aim of reducing vulnerability to risk and/or climate change?
2. Is the option technically feasible? Does the technology and/or expertise exist to carry out this measure?
3. Is the option financially/logistically feasible? Are there sufficient resources available to carry out this measure? How much would it cost to implement this measure and who would pay?
4. Are there any risks/negative effects associated with this option? Could there be any detrimental impacts on the ecosystem, local communities, agricultural production, and so on? Might the results of implementing this measure be unacceptable?

Additional criteria may be used that are not directly linked to the measures themselves, but are related to conditions that are in favour of that option. Such additional criteria include (GIZ, 2011):

1. Are there strong co-benefits? For instance, reforestation that prevents landslides also contributes to carbon sequestration and groundwater recharge.
2. Is there a high urgency? Is urgent action needed or what happens if no action is taken?
3. Is there a window of opportunities? If a plan comes into revision, is there a need to reconstruct infrastructure? Is there a person in charge in favour of certain ideas? Is it aligned with funding requirements? and so on.
4. Is the option a ‘no-regret’ option? Is the measure also beneficial in case the projected climatic changes do not occur?
5. When should the option be implemented? The timing of implementation of the option is relevant to determine the urgency of the measure, with a suggested classification into short term (< 5 years), mid-term (5–15 years) and long term (>15 years).

A comprehensive approach on the assessment and evaluation of proposed measures/strategies is proposed in the Climate Adaptation Methodology for Protected Areas (CAMPA)[49] that considers and compares benefits (DRR and CCA, other ecological and socioeconomic benefits), opportunities (in terms of policy and legislations, community support, complementarity with existing projects/funds), risks (ecological, social and economic risks associated with certain measures), and finally costs (taking into account capacity needs, resource and data/research needs).

On the basis of the various analyses and criteria, options for risk reduction measures are identified. The ‘best’ or ‘preferred’ option may involve a combination of elements from various options. In the end, there will never be one definitive and final set of measures. Rather, measures will need to be developed to address the effects that pose the highest risk to human health first, and efforts will continuously need to be made to better understand ongoing changes, like economic growth, urbanization, demography and climate change, and to develop appropriate measures to new and existing risks as they become better understood. This requires flexibility, and measures that are highly inflexible or where reversibility is difficult should be avoided.

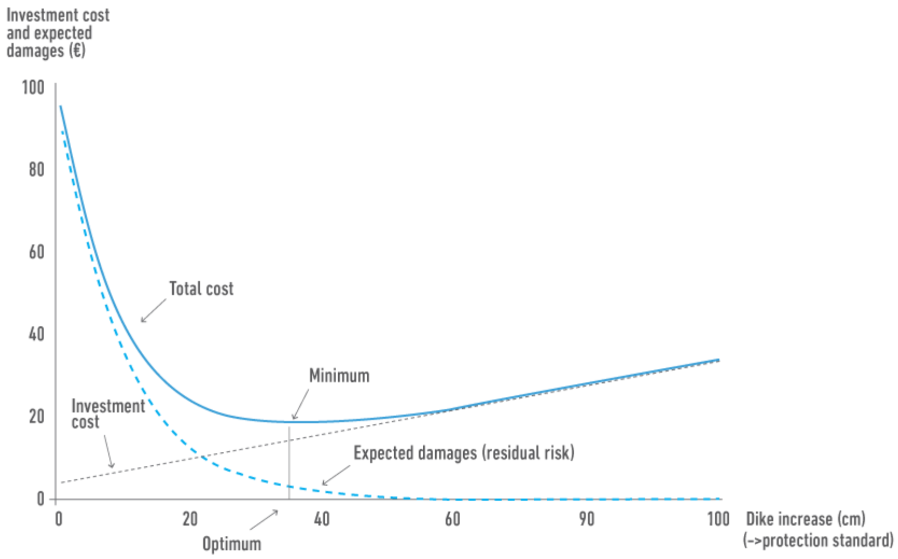
7.4.1 Cost–benefit analysis

The aim of a CBA is to find the optimum between the cost of an intervention and the cost of

[49] More information available from http://panda.org/campa

damages attributed to a disaster (Eijgenraam, 2006; Kind, 2014), and if unnecessary measures are taken then there is over-investment. The driving forces are economic growth (which potentially increases damage) and climate change (which increases the probability of disasters), and thus the cost of measures to compensate for increased damage are due to both issues. Sustainable development should also be considered here.

Figure 6. Cost-benefit analysis, the principle of marginal benefits equal to marginal costs for dike increase as an intervention



Source: Kind, 2014

The most appropriate model is chosen depending on the amount of time available for a study and the precise question. It is therefore important to have more than one available model to carry out risk analyses. The probability of flooding or drought can often be derived from historic events and it can be corrected for climate change. This estimation can be improved upon by using probabilistic models fed by hydrodynamic models (Geerse, 2011). Information from hydrodynamic models can in turn be improved upon by using climate models to generate artificial times series of hundreds/thousands of years. Consequences, damages and casualties are estimated by using population data and population density for a certain area. This can be improved by using damage modules in GIS information for how an area is built up. Investment costs can be estimated by determining average costs from past projects and using a nation price index to account for future corrections.

The essence of CBA lies in (APFM, 2007*a*):

- Identifying items of benefit and cost from an economic viewpoint, i.e. taking into account all the benefits accruing to and all the costs incurred by the economy or society as a whole.

- Selecting appropriate prices for evaluating the benefits and costs in monetary terms.
- Adjusting the future prices of costs and benefits to present values to make them comparable.

7.4.2 Multi-criteria analysis

Multi-criteria analysis is a two-stage decision procedure. The first stage identifies a set of goals or objectives and then seeks to identify the trade-offs between those objectives for different policies or for different ways of achieving a given policy. The second stage seeks to identify the 'best' policy by attaching weights (scores) to the various objectives. It involves judging the expected performance of each development option against a number of criteria or objectives. These techniques can deal with complex situations, involving uncertainty as well as the preferences of many stakeholders. This is particularly useful when the problem presents conflicting objectives and when these objectives cannot be easily expressed in monetary terms.

MCA involves judging the expected performance of each development option against a number of criteria or objectives and taking an overall view on the basis of a pre-assigned importance to each criterion. The essence of MCA lies in the preparation of a performance matrix with several rows and columns in which each row describes one of the options, and each column describes a criterion or performance dimension. Thereafter, scores for each option with respect to each criterion are assigned. These scores are supposed to represent performance indicators and are worked out through specific graphs or value functions for each criterion as based on scientific knowledge.

In the more sophisticated versions of MCA, weights are assigned to each criterion. Thereafter, a weighted average of scores is worked out. This average provides the overall indicator of performance of each option. The higher the weighted average of scores, the better the option. Weights determined by experts can however not be regarded as free from subjective biases. Weights determined by the concerned public would be regarded as free from the above problem. But this would suggest that the public is fully aware or conversant of all the criteria, which is often not the case.

Notwithstanding the shortcomings, MCA can be a useful supplement to CBA under certain situations. It could be used for shortlisting options, which can then be subjected to the more rigorous CBA for a final decision. In this respect MCA can be used as a framework for stakeholders to explore the nature of the choice and to identify the critical factors to discover their own preferences, and so on. (APFM, 2007*a*).

8. Implementation

8.1 Considerations for implementation

The final disaster risk management strategy should be endorsed at the appropriate political level (for example at the council of ministers or parliament, depending on the national situation or joint body). The agreed strategy should be published and brought to the attention of all stakeholders. The strategy should be accompanied by a clear time plan for the implementation of the measures, a clear distribution of responsibilities and a financial strategy. Implementation should start as early as possible after the strategy is agreed and should be regularly evaluated.

Uncoordinated sectoral responses can be ineffective or even counterproductive because responses in one sector can increase the vulnerability of another sector and/or reduce the effectiveness of adaptation responses in that sector. Hence, there is a need to adopt a cross-sectoral approach when formulating and evaluating options and implementing the strategy. This is even more important for water, on which many other sectors rely.

For effective disaster risk management strategies, measures need to be implemented at different time scales:

1. Long-term measures are related to decisions to address long-term (decadal) climate changes and are based on long-term projections. They usually exceed the scope of water sector planning because they affect the development model and the socioeconomic background through institutional and legal changes (e.g. land use planning).
2. Medium-term measures relate to decisions aimed at addressing medium-term (within one or two decades) (climate) trend projections and introducing the required corrections in the framework through hydrological planning measures such as risk management (for example, drought and flood management plans).
3. Short-term measures relate to decisions that address identified problems mainly under the current hydrological variability. They correspond to measures that can be adopted in the current institutional, legal and infrastructural frameworks (for example, revised water allocations during drought).

A common problem is the focus on short-term measures. Medium- and long-term planning should be fostered, although this is often difficult due to short electoral cycles, funding constraints, and the high uncertainty associated with medium- and long-term forecasts. Linking short, medium and longer term planning is necessary to ensure for instance that short-term measures do not hamper longer term ones.

Extreme events often alter risk and vulnerability perception among policy-makers, water managers and the population, generally raising their sense of urgency to undertake risk reduction measures, at least in the short term. Extreme events can therefore accelerate the implementation of medium- and long-term strategies and should be used accordingly. Droughts for example can be occasions to shift regional economies away from water-intensive crops to other forms of agriculture and economic activity that are less climate-sensitive.

8.1.1 The role of pilot projects

Pilot projects represent an important method for assessing the effectiveness of a DRR strategy. They can focus on a specific step of the strategy, a specific city or region, or any other aspect of the strategy. In order for effective learning to happen, pilot projects should include clear indicators of success as well as sufficient resources for monitoring and evaluation. In this way, they also support a learning-by-doing approach that enables users:

(a) To make midcourse corrections to the implementation of DRR strategies, so that they meet their objectives more efficiently.
(b) To improve their understanding of what determines adaptive capacity so that capacity development activities can be more successful from the outset.

To learn from mistakes and successes, it is important to combine these insights into:

(a) A comparison of the actual experience with the initial appraisal of the situation and with the criteria adopted.
(b) The construction of a revised DRR baseline that describes how the system would have performed in the absence of DRM.

8.2 Exchange of experience and knowledge

Establishing an international platform is important for exchanging lessons learned, best practices and failures. As there is little experience available in developing DRR strategies and measures at the transboundary level, knowledge developed by countries and experiences in implementing measures in basins, both successful and less successful examples, can help other countries to reduce risks, including environment-related health risks, and thus improve their DRR strategies.

Decision makers have found that scheduling reviews and updates of the disaster risk and climate adaptation strategy on a fixed schedule is a useful means of ensuring its long-term flexibility. Political processes may benefit by having fixed-term re-assessments of risks and vulnerability (and the processes of evaluating them), which can then explicitly inform transboundary institutions such as the reallocation of water resources, the planning of new infrastructure, or the operating regime of existing infrastructure to match shifting conditions and changing needs.

Participatory processes in support of DRR can add value, enhance feasibility and acceptance, and lead to more accurate results. Engaging as many stakeholders as possible can democratize the overall process of risk prevention and mitigation, and help in adapting to climate change and climate variability. For example, stakeholder engagement can uncover obstacles and reasons for the failure of measures, such as scepticism on the part of stakeholders about the information provided by government. However, participatory evaluation needs to go hand-in-hand with scientific evaluation which often takes into account more long-term issues (OECD, 2015*a*; UNECE, 2009*a*; UNECE, 2015).

8.3 Financing risk management measures

In general, costs of implementation of climate change adaptation measures and disaster risk management measures should be borne by each country, and governments should make efforts to include budgets and economic incentives in relevant bilateral and multilateral programmes for this purpose. Regarding financial arrangements, riparian countries should focus on generating basin-wide benefits and on sharing those benefits in a manner that is agreed as fair. A focus on sharing the benefits derived from the use of water, rather than the allocation of water itself, provides far greater scope for identifying mutually beneficial cooperative actions[50] and is a good basis for developing and implementing a disaster risk management strategy.

Payments for benefits (or compensation for costs) might be made in the context of cooperative arrangements. For instance, in a transboundary context, measures that support adaptation in one

[50] Also see https://blog.waterdiplomacy.org/2017/09/value-creation-in-transboundary-water-negotiations/

country might be more effective if they are implemented in another country. Prevention of drought or flooding, for instance, might be realized by creating retention areas upstream, which may be located in an upstream country. Financing of such measures should be equitably shared, and the party that gains most, pays more. Riparian countries can be compensated for example for land flooding as a consequence of water seizures by another riparian country. In some instances, it might be appropriate to make payments to an upstream country for managed practices of the basin that bring benefits downstream (for example, reduced flooding and sediment loads or improved water quality). This solidarity in the basin might entitle upstream countries to share some portion of the downstream benefits that their practices generate, thus sharing the costs of these practices.

The poorest countries that are often the most vulnerable to climate change should be supported by more affluent countries in their development towards climate proofing in terms of water management. Financial as well as ecological sustainability can be improved by recognizing water as an economic good and recovering the costs as much as possible from the users. Cost recovery from water users is an important funding source that can be directly linked to the intensity of use. This means that users are more aware of the consequences of their activities and it prevents overexploitation (Timmerman and Bernardini, 2009).

External financing for adaptation and resilience-building can take many forms and come from a wide variety of sources. There is also a wide variety of instruments and institutions for channeling finance to countries for the implementation of projects. Each fund or donor has differing rules and procedures when applying for financing and for implementing projects, as well as the levels of autonomy that occur. The level of autonomy for a country is linked to and can be limited by the level of donor involvement. Both autonomy and involvement have benefits and limitations. When identifying an appropriate funding source, the beneficiary should carefully consider its needs and circumstances on a project-by-project basis.

8.4 Insurance and reinsurance

Insurance can play an important role in reducing disaster risk. In the face of extreme weather events, well-functioning insurance markets transfer the risk of these events across a large pool of individuals or businesses. Insurance protects capital outlay, enhances solvency, allows recovery, and if designed carefully, has the potential to encourage risk reduction behaviour. In the absence of insurance, these risks would be too large for private individuals and businesses to bear on their own. Insurance can work only for risks that are insurable. The main principles of insurability are: i) risks have to be quantifiable; ii) occur randomly; and iii) be sufficiently numberous so that variations in claims are smoothed out. From the client’s side, the premiums have to be affordable and the contract has to perform reliably.

There is also a role for the international community to facilitate adaptation to climate change through disaster risk reduction and insurance, especially in poorer countries. Insurance can support disaster preparedness and management if it is accompanied by requirements or incentives to take preventive measures and it can therefore constitute an important element of a cost-effective adaptation to climate change risks. But traditional insurance may not be the most appropriate tool for longer term foreseeable risks like sea-level rise, for which a greater emphasis on and investment in basic risk reduction measures is more appropriate.

Different insurance models exist. In an insurance model where everyone contributes, the costs of extreme events to the most vulnerable are cross-subsidized by those at lower risk. This principle typically underlies government-backed insurance systems. An important drawback of such a system is that it creates moral hazard by offering no reward to those that take steps to reduce their vulnerability and adverse selection. For these reasons, the level of government subsidies should be set with great care. Market-based models distinguish between those users at greatest risk who pay more to the scheme than those who avoid risk. This leads to an efficient risk-based pricing. However, the drawback is that such an approach can exclude the most financially vulnerable. Governments therefore have a role in creating a financial safety net to protect the poor.

Reinsurance refers to the insurance of insurance companies. Whenever the insurer cannot or does not wish to take the entire risk and wants to reduce the likelihood of having to pay a large obligation as the result of an insurance claim, the insurer resorts to reinsurance, thereby protecting itself from the losses incurred by catastrophe. This is a mechanism whereby insurers transfer a portion of the risk portfolio to other parties. The reinsurance company receives pieces of a larger potential obligation in exchange for some of the money received by the original insurers to accept the obligation.

Given the potentially vast scale of disasters and their ability to overwhelm the coping capacity of single countries, there is significant scope for recognizing the benefits of regional cooperation in the area of disaster risk management, particularly risk financing. Public-private partnerships to promote the development and use of climate-related insurance markets also offer great potential for supporting adaptation (APFM, 2013*b*; UNECE, 2009*a*).

9. Monitoring and evaluation

9.1 How is it implemented?

Evaluation is a process for systematically and objectively determining the relevance, efficiency, effectiveness and impact of strategies in light of their objectives. Evaluating DRR strategies is imperative to assess their results and impacts, and to provide a basis for decision-making on amendments and improvements to policies, strategies, programme management, procedures and projects. Evaluation is the responsibility of decision makers and it should guide and support government decision-making and policymaking, as well as international aid and investment. It should also support prioritizing strategies and initiatives that reduce vulnerability to disasters.

A basin-wide DRR strategy should be based on an evaluation that covers the entire basin. The evaluation should therefore be carried out as a joint activity by riparian countries based on their shared objectives. It should for example consider whether benefits have accrued to all riparian countries as planned, or whether adjustments need to be made. Consultations and preferably the establishment of a joint evaluation committee will be required.

Evaluation and monitoring activities are essential for verifying the effectiveness and efficiency of the measures taken and for facilitating adjustments. Evaluation is carried out during implementation (ongoing evaluation), at the completion of an activity (final evaluation), and some years after completion (post evaluation). Part of the evaluation can be based on self-assessment by the staff responsible, but external evaluation is also recommended.

Evaluation should be based on indicators that focus on the progress in the implementation of a policy (process indicators) and indicators that represent progress towards a specific objective (outcome indicators). The policy and institutional framework can best be evaluated by process indicators, which demonstrate actual, on-the-ground institutional and political progress in the often time-consuming, step-by-step journey to solving complex problems. They assist in tracking the domestic and regional institutional, policy, legislative and regulatory reforms necessary to bring about change. Monitoring progress in DRR includes collecting information on the progress made towards achieving objectives, i.e. the outcome indicators. Six types of outcome indicators that measure the success of DRR strategies can be distinguished:

1. *Coverage*: the extent to which the strategy reaches vulnerable stakeholders (e.g. individuals, households, businesses, government agencies, policymakers) and ecosystems.
2. *Impact*: the extent to which the strategy reduces risk and/or enhances adaptive capacity (e.g. through bringing about changes in the DRM processes: policymaking/planning, capacity-building/ awareness-raising, information management).
3. *Sustainability*: the ability of stakeholders to continue the DRM processes beyond activity/project lifetimes, thereby sustaining development benefits.
4. *Replicability*: the extent to which strategies generate and disseminate results and lessons of value in other, comparable contexts.
5. *Effectiveness*: the extent to which the objective has been achieved, or the likelihood that it will be achieved.
6. *Efficiency*: the outputs in relation to inputs, looking at costs, implementation time, and economic and financial results. In measuring efficiency, it is important to remember that long-term objectives (as dealt with in climate change adaptation) require cost-benefit analysis that takes account of long-term developments.

Indicators can be quantitative or qualitative and should describe the positive and negative effects of interventions. They should be defined from the beginning, i.e. when DRR measures and objectives are decided upon in order to enable continuous data collection and evaluation. Evaluating DRR strategies includes evaluating the constituent elements of a given strategy: the policy, legal and institutional setting; financial arrangements; vulnerability assessment; and the choice and implementation of measures. It also includes monitoring progress towards achieving its objectives.

Evaluation of DRR strategies should also include performance under climate impacts (for example, is the overall impact of an extreme event lower than before given similar circumstances?), a comparison of one project area with another similar area where no intervention took place, and measuring outcome against standards (e.g. benchmarking) and targets (OECD, 2015*a*; UNECE, 2009*a*; UNECE, 2015).

9.2 Reporting under the Sendai Framework and the SDGs

A set of indicators were identified to measure global progress in the implementation of the Sendai Framework for Disaster Risk Reduction. The indicators will measure progress in achieving the global targets of the Sendai Framework, and determine global trends in the reduction of risk and losses. These metrics, together with indicators that can be employed by countries to measure nationally determined targets, will allow for an appraisal of the impact actions of stakeholders supporting the achievement of the outcome, goals and targets of the Sendai Framework. The indicators will generate the information base for the development of Sendai Framework implementation strategies, facilitate the development of risk-informed policies and decision-making processes, and guide the allocation of appropriate resources. Key indicators, measuring the global targets of the Sendai Framework, have been adopted for use in measuring disaster-related goals and targets of the 2030 Agenda for Sustainable Development, thereby allowing the simultaneous and coherent monitoring and reporting on the Sendai Framework and SDGs 1, 11 and 13.[51]

Progress in implementing the Sendai Framework will be assessed biennially by UNISDR, and analysis and trends will be presented in the Sendai Framework Progress Report. Countries will be able to report against the indicators for measuring the global targets of the Sendai Framework, as well as the disaster risk reduction-related indicators of the SDGs, using the online Sendai Framework Monitor. The Sustainable Development Goals Report is submitted every year to the High-level Political Forum on Sustainable Development (HLPF), for which countries are expected to collect data and report on an annual basis.

The Sendai Framework recognizes that the Global and Regional Platforms for Disaster Risk Reduction have a key role in its implementation. The Global Platform and Regional Platforms are inter alia expected to periodically monitor and assess progress in implementation, and contribute to the deliberations of the HLPF, the United Nations General Assembly and the United Nations Economic and Social Council, including the integrated and coordinated follow-up processes to United Nations conferences and summits, and the quadrennial comprehensive policy reviews of the United Nations operational activities for development.

9.3 Sound evaluations

Sound evaluations can be carried out with simple but careful examinations of success relative to expectations. The following list provides examples of questions that could contribute to this evaluation:

[51] More information available from: https://www.preventionweb.net/drr-framework/sendai-framework-monitor/

(a) If, for instance, DRR involved investing in a protection project in response to a climate hazard, then the evaluation should determine whether losses have continued, grown or lessened.
(b) If the protection project simply tried to reduce sensitivity to extreme events, has it worked and if so, how?
(c) Have episodes of intolerable exposure become more or less frequent?
(d) Has the definition of 'intolerable' in terms of physical impacts changed?
(e) Has the investment expanded the coping range and reduced exposure to intolerable outcomes that exceed the range, or both?
(f) Have things stayed the same or become worse because the DRR measure was ineffective, or because unanticipated stresses have aggravated the situation?
(g) Is there a causal relationship between vulnerability reduction and the strategy/measure?

If the aims of a DRR strategy have not been reached, the root causes of both successes and failures should be analysed. This can be done through various methods, for example by conducting a survey among the population, expert interviews, site visits, and so on.

10. Glossary

This glossary lists the most important terms used in this guide but it is not intended to give a complete list of terms related to disaster risk management and climate change adaptation. For a full overview, please use the glossaries as referenced.

Adaptation

- ➢ Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (UNFCCC, 2017).
- ➢ The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities (IPCC, 2014).

Adaptive capacity

The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2014).

Capacity

The combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience. Capacity may include infrastructure, institutions, human knowledge and skills, and collective attributes such as social relationships, leadership and management (UNISDR, 2017).

- **Coping capacity** is the ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks.
- **Capacity assessmen**t is the process by which the capacity of a group, organization or society is reviewed against desired goals where existing capacities are identified for maintenance, or strengthening and capacity gaps are identified for further action.
- **Capacity development** is the process by which people, organizations and society systematically stimulate and develop their capacities over time to achieve social and economic goals. It is a concept that extends the term of capacity-building to encompass all aspects of creating and sustaining capacity growth over time. It involves learning and various types of training, but also continuous efforts to develop institutions, political awareness, financial resources, technology systems and the wider enabling environment.

Capacity-building

In the context of climate change, the process of developing the technical skills and institutional capability in developing countries and economies in transition to enable them to address effectively the causes and results of climate change (UNFCCC, 2017).

Climate change

- ➢ Refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that Article 1 of the UNFCCC defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes (IPCC, 2014).

- Long term modification of the climate resulting from one or more of the following factors: i) internal changes within the climate system; ii) interaction between the climatic components; and iii) changes in external forces caused by natural phenomena or by human activities (WMO, 2012).

Disaster

- Serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts. The effect of the disaster can be immediate and localized, but is often widespread and can last for a long period of time. The effect may test or exceed the capacity of a community or society to cope using its own resources, and therefore may require assistance from external sources, which could include neighbouring jurisdictions, or those at the national or international levels (UNISDR 2017).
- Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs that may require external support for recovery (IPCC, 2014).

Disaster risk

The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity. The definition of disaster risk reflects the concept of hazardous events and disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socio economic development, disaster risks can be assessed and mapped, in broad terms at least. It is important to consider the social and economic contexts in which disaster risks occur and that people do not necessarily share the same perceptions of risk and their underlying risk factors (UNISDR, 2017).

- **Acceptable risk** or tolerable risk is therefore an important subterm; the extent to which a disaster risk is deemed acceptable or tolerable depends on existing social, economic, political, cultural, technical and environmental conditions. In engineering terms, acceptable risk is also used to assess and define the structural and non-structural measures that are needed in order to reduce possible harm to people, property, services and systems to a chosen tolerated level, according to codes or "accepted practice" which are based on known probabilities of hazards and other factors.

- **Residual risk** is the disaster risk that remains even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained. The presence of residual risk implies a continuing need to develop and support effective capacities for emergency services, preparedness, response and recovery, together with socioeconomic policies such as safety nets and risk transfer mechanisms, as part of a holistic approach.

Intensive and extensive disaster risk (UNISDR, 2017)

- **Extensive disaster risk**: the risk of low-severity, high-frequency hazardous events and disasters, mainly but not exclusively associated with highly localized hazards. Extensive disaster risk is usually high where communities are exposed and vulnerable to recurring localized floods, landslides, storms or drought. Extensive disaster risk is often exacerbated by poverty, urbanization and environmental degradation.
- **Intensive disaster risk**: the risk of high-severity, mid- to low-frequency disasters, mainly associated with major hazards. Intensive disaster risk is mainly a characteristic of large cities or densely populated areas that are not only exposed to intense hazards, such as strong earthquakes, active volcanoes, heavy floods, tsunamis or major storms, but also have high levels of vulnerability to these hazards.

Disaster risk assessment

A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend. Disaster risk assessments include: i) the identification of hazards; ii) a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; iii) the analysis of exposure and vulnerability, including the physical, social, health, environmental and economic dimensions; and iv) the evaluation of the effectiveness of prevailing and alternative coping capacities with respect to likely risk scenarios (UNISDR, 2017).

Disaster risk governance

The system of institutions, mechanisms, policy and legal frameworks and other arrangements to guide, coordinate and oversee disaster risk reduction and related areas of policy. Good governance needs to be transparent, inclusive, collective and efficient to reduce existing disaster risks and avoid creating new ones (UNISDR, 2017).

Disaster risk management

Application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses. Disaster risk management actions can be distinguished between prospective disaster risk management, corrective disaster risk management and compensatory disaster risk management, also called residual risk management (UNISDR, 2017).

Disaster risk reduction

Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development. Disaster risk reduction is the policy objective of disaster risk management, and its goals and objectives are defined in disaster risk reduction strategies and plans. Disaster risk reduction strategies and policies define goals and objectives across different timescales and with concrete targets, indicators and time frames. In line with the Sendai Framework for Disaster Risk Reduction 2015–2030, these should be aimed at preventing the creation of disaster risk, the reduction of existing risk, and the strengthening of economic, social, health and environmental resilience (UNISDR, 2017).

Drought

- A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed agricultural drought) and during the runoff and percolation season primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought. A megadrought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more (IPCC, 2014).
- Meteorological drought: prolonged absence or marked deficiency of precipitation (WMO, 2012).
- Hydrological drought: period of abnormally dry weather sufficiently prolonged to give rise to a shortage of water as evidenced by below normal streamflow and lake levels and/or the depletion of soil moisture and a lowering of groundwater levels (WMO, 2012).
- *Droughts* can be considered as a temporary decrease of the average water availability due to for example rainfall deficiency. The impact of droughts can be exacerbated when they occur in a region with low water resources or where water resources are not being properly managed resulting in imbalances between water demands and the supply capacity of the natural system. *Water scarcity* occurs where there are insufficient water resources to satisfy long term average requirements. It refers to long term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system (http://ec.europa.eu/environment/water/quantity/about.htm).

Early warning system

An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities, systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events. Effective ‘end-to-end’ and ‘people-centred’ early warning systems may include four interrelated key elements: i) disaster risk knowledge based on the systematic collection of data and disaster risk assessments; ii) detection, monitoring, analysis and forecasting of the hazards and possible consequences; iii) dissemination and communication, by an official source, of authoritative, timely, accurate and actionable warnings and associated information on likelihood and impact; and iv) preparedness at all levels to respond to the warnings received. These four interrelated components need to be coordinated within and across sectors and at multiple levels for the system to work effectively, and to include a feedback mechanism for continuous improvement. Failure in one component or a lack of coordination across them could lead to the failure of the whole system (UNISDR, 2017).

Exposure

- The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas. Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability and capacity of the exposed elements to any particular hazard so as to estimate the quantitative risks associated with that hazard in the area of interest (UNISDR, 2017).
- The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected (IPCC, 2014).

Flood

- The overflow of the normal confines of a stream or other body of water, or the accumulation of water over areas not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods and glacial lake outburst floods (IPCC, 2014).
- (1) A rise, usually brief, in the water level of a stream or water body to a peak from which the water level recedes at a slower rate. (2) A relatively high flow as measured by stage height or discharge (WMO, 2012).

Hazard

- A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. Hazards may be natural, anthropogenic or socio-natural in origin. Natural hazards are predominantly associated with natural processes and phenomena. Anthropogenic hazards or human-induced hazards are induced entirely or predominantly by human activities and choices. This term does not include the occurrence or risk of armed conflicts and other situations of social instability or tension that are subject to international humanitarian law and national legislation. Several hazards are socio-natural in that they are associated with a combination of natural and anthropogenic factors, including environmental degradation and climate change. Hazards may be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity or magnitude, frequency and probability. Biological hazards are also defined by their infectiousness or toxicity, or other characteristics of the pathogen such as dose-response, incubation period, case fatality rate and estimation of the pathogen for transmission (UNISDR, 2017).
- The potential occurrence of a natural or human-induced physical event, trend or physical impact that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends, or their physical impacts (IPCC, 2014).

Impacts (consequences, outcomes)

Effects on natural and human systems. In this report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period, and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts and sea level rise are a subset of impacts called physical impacts (IPCC, 2014).

Mitigation

- The lessening or minimizing of the adverse impacts of a hazardous event. The adverse impacts of hazards, in particular natural hazards, often cannot be prevented fully, but their scale or severity can be substantially lessened by various strategies and actions. Mitigation measures include engineering techniques and hazard-resistant construction as well as improved environmental and social policies and public awareness. It should be noted that in climate change policy, "mitigation" is defined differently and is the term used for the reduction of greenhouse gas emissions that are the source of climate change (UNISDR, 2017).
- In the context of climate change, a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings, and expanding forests and other "sinks" to remove greater amounts of carbon dioxide from the atmosphere (UNFCCC, 2017).
- A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs). This report also assesses human interventions to reduce the sources of other substances may contribute directly or indirectly to limiting climate change, including for example the reduction of particulate matter emissions that can directly alter the radiation balance (e.g. black carbon) or measures that control emissions of carbon monoxide, nitrogen oxides, Volatile Organic Compounds and other pollutants that can alter the concentration of the tropospheric ozone, which has an indirect effect on the climate (IPCC, 2014).
- Structural flood mitigation: reduction of the effects of a flood using physical solutions, such as reservoirs, levees, dredging and diversions (WMO, 2012).

Preparedness

The knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters. Preparedness action is carried out within the context of disaster risk management and aims to build the capacities needed to efficiently manage all types of emergencies and achieve orderly transitions from response to sustained recovery. Preparedness is based on a sound analysis of disaster risks and good linkages with early warning systems and includes such activities as contingency planning, the stockpiling of equipment and supplies, the development of arrangements for coordination, evacuation and public information, and associated training and field exercises. These must be supported by formal institutional, legal and budgetary capacities. The related term "readiness" describes the ability to quickly and appropriately respond when required (UNISDR, 2017).

Prevention

The activities and measures to avoid existing and new disaster risks. Prevention (i.e., disaster prevention) expresses the concept and intention to completely avoid potential adverse impacts of hazardous events. While certain disaster risks cannot be eliminated, prevention aims at reducing vulnerability and exposure in such contexts where, as a result, the risk of disaster is removed.

Examples include dams or embankments that eliminate flood risks, land use regulations that do not permit any settlement in high-risk zones, seismic engineering designs that ensure the survival and function of a critical building in any likely earthquake, and immunization against vaccine-preventable diseases. Prevention measures can also be taken during or after a hazardous event or disaster to prevent secondary hazards or their consequences, such as measures to prevent the contamination of water (UNISDR, 2017).

Reconstruction

The medium term and long term rebuilding and sustainable restoration of resilient critical infrastructures, services, housing, facilities and livelihoods required for the full functioning of a community or a society affected by a disaster, aligning with the principles of sustainable development and "build back better" to avoid or reduce future disaster risk (UNISDR, 2017).

Recovery

Restoring or improving livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities of a disaster-affected community or society, and aligning with the principles of sustainable development and "build back better" to avoid or reduce future disaster risk (UNISDR, 2017).

Resilience

- ➢ The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNISDR, 2017).
- ➢ The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation (IPCC, 2014).
- ➢ Property of a water system to be in a state of equilibrium in spite of various ecological disturbances which it experiences (WMO, 2012).

Response

Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. Disaster response is predominantly focused on immediate and short-term needs and is sometimes called disaster relief. An effective, efficient and timely response relies on disaster risk-informed preparedness measures, including the development of response capacities of individuals, communities, organizations, countries and the international community. The institutional elements of response often include the provision of emergency services and public assistance by public, private and community sectors, as well as community and volunteer participation. 'Emergency services' are a critical set of specialized agencies that have specific responsibilities in serving and protecting people and property in emergency and disaster situations. They include civil protection authorities and police and fire services, among many others. The division between the response stage and the subsequent recovery stage is not clear-cut. Some response actions, such as the supply of temporary housing and water supplies, may extend well into the recovery stage (UNISDR, 2017).

Risk

The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. In this report, the term risk is often used to refer to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure (IPCC, 2014).

Risk management

The plans, actions or policies to reduce the likelihood and/or consequences of risks or to respond to consequences (IPCC, 2014).

Structural and non-structural measures

- *Structural measures* are any physical construction to reduce or avoid possible impacts of hazards, or the application of engineering techniques or technology to achieve hazard resistance and resilience in structures or systems. *Non-structural measures* are measures not involving physical construction which use knowledge, practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness-raising, training and education. Common structural measures for disaster risk reduction include dams, flood levees, ocean wave barriers, earthquake-resistant construction and evacuation shelters. Common non-structural measures include building codes, land-use planning laws and their enforcement, research and assessment, information resources and public awareness programmes. Note that in civil and structural engineering, the term "structural" is used in a more restricted sense to mean just the load-bearing structure, and other parts such as wall cladding and interior fittings, are termed "non-structural" (UNISDR, 2017).
- *Structural* flood mitigation: reduction of the effects of a flood using physical solutions, such as reservoirs, levees, dredging and diversions. *Non-structural* flood mitigation: systems for reducing the effects of floods using non-structural means, such as land-use planning, advanced warning systems and flood insurance (WMO, 2012).

Sustainability

A dynamic process that guarantees the persistence of natural and human systems in an equitable manner (IPCC, 2014).

Sustainable development

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (IPCC, 2014; UNFCCC, 2017).

Uncertainty

- A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain

projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g. a probability density function) or by qualitative statements (e.g. reflecting the judgment of a team of experts) (IPCC, 2014).
- Estimate of the range of values within which the true value of a variable lies (WMO, 2012).

Vulnerability

- The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (UNISDR, 2017).
- The degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (UNFCCC, 2017).
- The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and a lack of capacity to cope and adapt (IPCC, 2014).
- (of groundwater) Extent to which groundwater is at risk of pollution (WMO, 2012).

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