ICPDR Strategy on Adaptation to Climate Change

icpdr iksd

International Commission for the Protection of the Danube River

Internationale Kommission zum Schutz der Donau

//// Deutschland //// Österreich //// Česká republika //// Slovensko //// Magyarország //// Slovenija //// Hrvatska //// Bosna i Hercegovina //// Србија //// Crna Gora //// România //// България //// Moldova //// Україна //

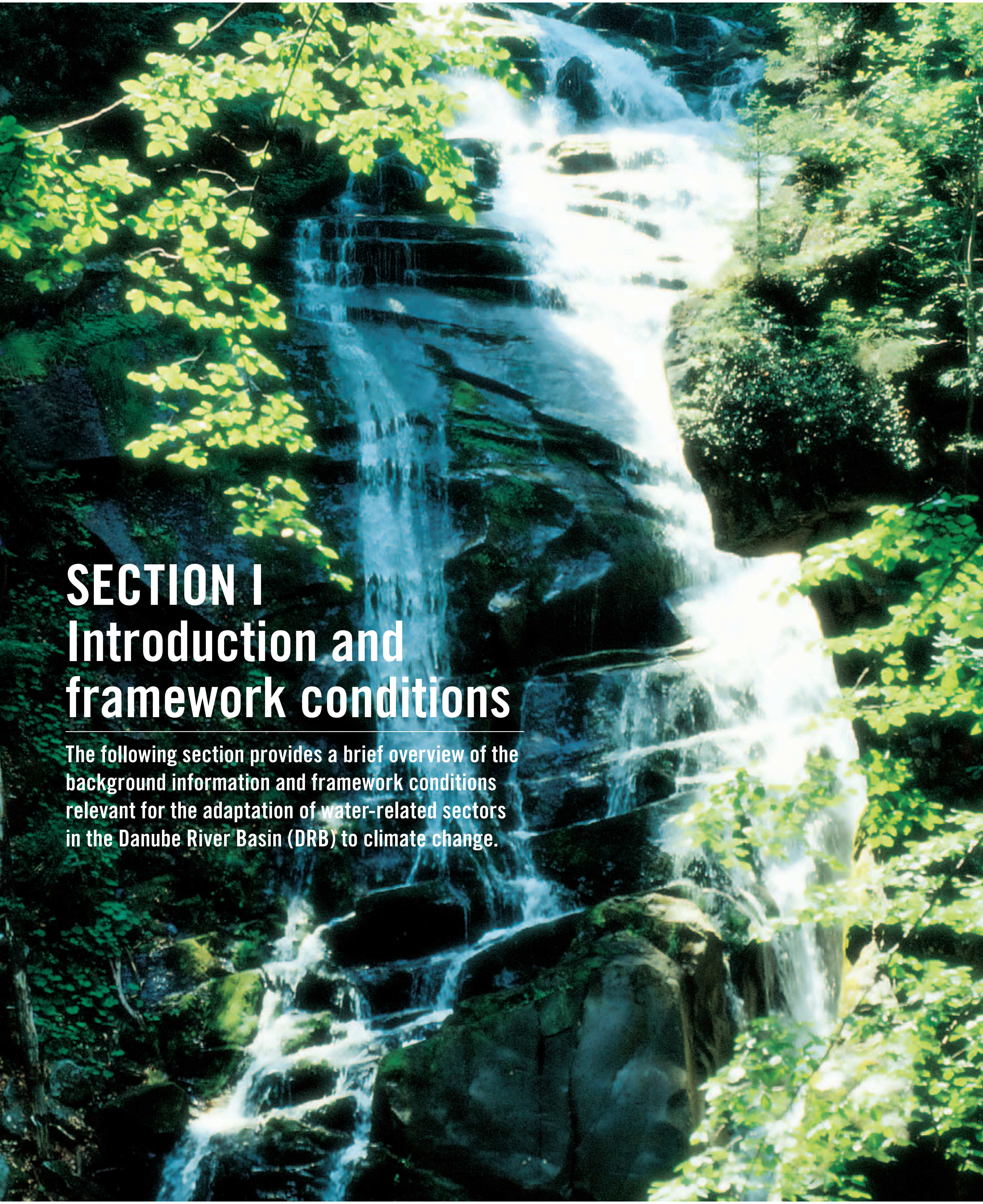
"Water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change"

(IPCC Technical paper "Climate Change and water", June 2008)

Table of contents

List of Acronyms

CIS	Common Implementation Strategy for the Water Framework Directive
CLIMATE-ADAPT	European Climate Adaptation Platform
DRB	Danube River Basin
DFRM Plan	Danube Flood Risk Management Plan
DJF	December/January/February
DRBM Plan	Danube River Basin Management Plan
EC	European Commission
EEA	European Environment Agency
EFD	European Floods Directive
EU	European Union
GCM	Global Circulation Model
GHG	Greenhouse gas
ICPDR	International Commission for the Protection of the Danube River
IPCC	Intergovernmental Panel on Climate Change
JJA	June/July/August
LDRB	Lower Danube River Basin
MDRB	Middle Danube River Basin
RBD	River Basin District
RCM	Regional Climate Models
RBM	River Basin Management
RBMP	Danube River Basin Management Plan
SRES	Special Report on Emissions Scenarios
UDRB	Upper Danube River Basin
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
WFD	Water Framework Directive



SECTION I
Introduction and framework conditions

The following section provides a brief overview of the background information and framework conditions relevant for the adaptation of water-related sectors in the Danube River Basin (DRB) to climate change.

1 Introduction

1.1 Background

Climate change is scientifically confirmed worldwide, *inter alia*, by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)[1]. Despite ambitious international climate protection objectives and activities, adaptation to climate change impacts is urgently needed. Water, together with temperature, is in the centre of the expected changes. Due to the fact that water is a cross-cutting issue with major relevance for different sectors, water is the key for taking the required adaptation steps. In the Danube River Basin, climate change is likely to cause significant impacts on water resources and can develop into a significant threat if the reduction of greenhouse gas emissions is not complemented by climate adaptation measures.

1.2 Mandate

In February 2010, ministers and high-level representatives responsible for water management in the Danube countries and from the European Union endorsed the 'Danube Declaration'[2], which expresses the commitment to further reinforce transboundary cooperation on sustainable water resources management within the Danube River Basin, including adaptation to climate change.

In order to take the required steps on adaptation, the ICPDR was asked in the Danube Declaration to develop until 2012 a Climate Adaptation Strategy for the Danube River Basin. This strategy should be based on a step-by-step approach and encompass an overview of relevant research and data collection, a vulnerability assessment, ensure that measures and projects are climate proof respectively "no regret measures" and ensure that climate adaptation issues are fully integrated in the 2nd Danube River Basin Management Plan in 2015. The Danube Declaration therefore constitutes the mandate for the elaboration of the 'ICPDR Strategy on Adaptation to Climate Change'.

1 *Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. & Miller, H. L. (2007): Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, United Kingdom and New York, USA.*

2 *Danube Declaration: http://www.icpdr.org/main/sites/default/files/Ministerial%20Declaration%20FINAL.pdf*

1.3 Relevance for 2nd DRBM Plan and 1st DFRM Plan

In 2000, the European Union adopted the EU Water Framework Directive (WFD). The directive requires water management according to the outlines of natural river basins. The ICPDR is the platform for coordination of the implementation of the WFD on the Danube basin-wide scale. The WFD, together with the EU Floods Directive (EFD) from 2007, are of highest priority for the ICPDR, as all its contracting parties, including non-EU countries, agreed to a coordinated implementation.

As a result of these efforts, the 1st Danube River Basin Management Plan (1st DRBM Plan) was developed based on the principles of the WFD and adopted by the ICPDR in 2009. It included the first conclusions on the need for climate adaptation. According to the six-year management cycle of the WFD, the Danube River Basin Management Plan will be reviewed and updated by the end of 2015 (2nd DRBM Plan). This is the same target date as for the elaboration of the 1st Danube Flood Risk Management Plan (1st DFRM Plan) according to the EFD, which will, in the future, also be reviewed and updated in six-year planning cycles.

Both directives and related management plans are key tools for the adaptation of the water sector to climate change, including the issue of water scarcity and droughts. The underpinning rationale and processes for the implementation of the WFD and EFD are as well applicable to approach the issue of climate adaptation. In particular, the integrated approaches to water and ecosystem management, combined with the cyclical review of progress achieved, are consistent with the basic principles of adaptive management which is specifically important for climate change adaptation. In addition, climate change impacts upstream can have implications downstream and vice versa. Therefore, international cooperation as part of the implementation of both directives plays an important role.

However, certain limitations have to be pointed out in terms of what can be delivered in the frame of the ICPDR on adaptation. These limitations are two-fold: touching on one hand the level of detail which can be achieved in adaptive planning on the Danube basin-wide scale; on the other hand the relevance for different sectors concerned. A demarcation of action fields for the ICPDR is therefore required. While the focus should be on integrative planning for the water sector on issues relevant at the basin-wide scale, more detailed planning has to take place at the sub-basin and/or national level, which may deliver further detailed adaptation actions and strategies that additionally cover non water-related sectors.

2 Framework conditions

2.1 Relevant water-related EU Directives and Policies

Several existing EU Directives and policies contribute to efforts for adaptation to climate change with regard to water issues. As indicated, the most important ones are the WFD (and its daughter directives) and the EFD. However, other policies such as the Water Scarcity and Droughts EU Policy and the EC's White Paper on Adaptation are important building blocks for adaptation (see Chapter 2.2). In the following, a brief overview of the WFD and EFD as the key tools for adaptation is provided.

2.1.1 The EU Water Framework Directive 2000/60/EC

The Water Framework Directive 2000/60/EC (WFD)[3] establishes a legal framework to protect and restore the water environment and to ensure the long-term sustainable use of water. Although climate change is not explicitly included in the text of the WFD, the step-wise and cyclical approach of the WFD river basin management process makes it well-suited to handle climate change (explained in detail in the EU CIS Guidance No. 24[4]).

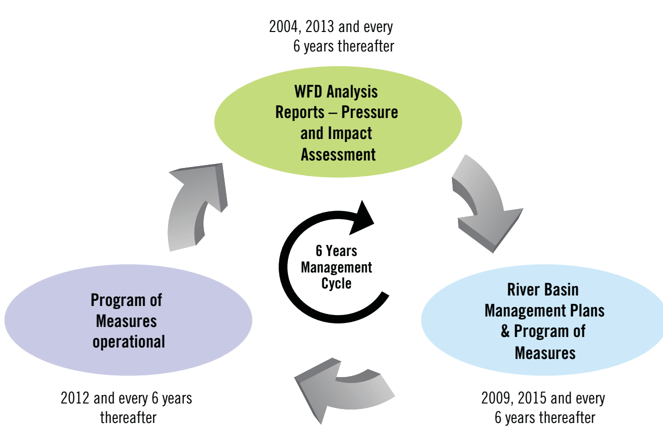
Climate change should be comprehensively considered in the different steps of the WFD implementation and RBM planning and implementation process, such as characterisation, analysis of pressures and impacts, economic analysis, monitoring, design of the programmes of measures and the default and water body objective setting processes (see Figure 1).

Climate change impacts may increase, but in some cases as well moderate pressures on water resources. Therefore, it is important that the next Danube River Basin Management Plans take account of the medium- and long-term implications of climate change, as there is a large potential for synergies between objectives setting and adaptation aims. Thus, the 2nd DRBM Plan due in 2015 should already be designed to be robust to the impacts of climate change and climate variability. As such, it must be ensured that measures are either flexible enough to be adjusted appropriately to changing climate conditions or that those of a fixed nature with a longer term life incorporate climate projections in their design.

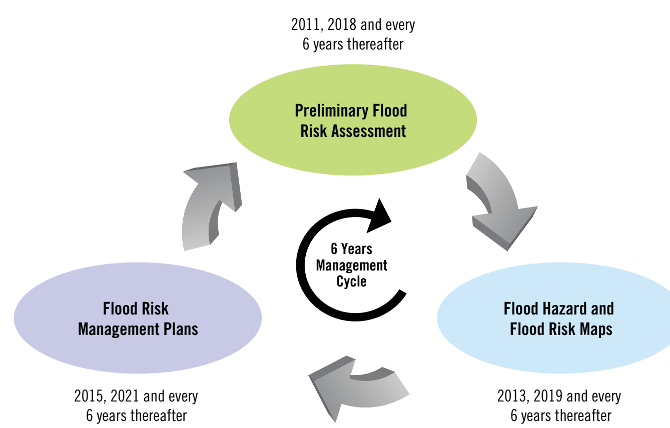
2.1.2 The EU Floods Directive 2007/60/EC

The EU Floods Directive 2007/60/EC (EFD)[5] establishes a legal framework for the assessment and management of flood risks, aiming at reducing the adverse consequences of floods to human health, the environment, cultural heritage and economic activity. The directive requires, *inter alia*, the elaboration of the 1st DFRM Plan by 2015 for those areas where potential significant flood risk has been assessed. The Management Plan should provide adequate and coordinated measures to reduce this flood risk, taking into account the possible impact of climate change. The core elements of the flood risk management cycle are the preliminary flood risk assessment (accomplished for the Danube River Basin in March 2012), flood hazard and risk maps and flood risk management plans (see Figure 2).

Main implementation steps for the EU Water Framework Directive *FIGURE 1*



Main implementation steps for the EU Floods Directive *FIGURE 2*



3 *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:NOT*

4 *European Communities (2009): Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 24. River Basin Management in a Changing Climate. Technical Report, Nr. 40.*

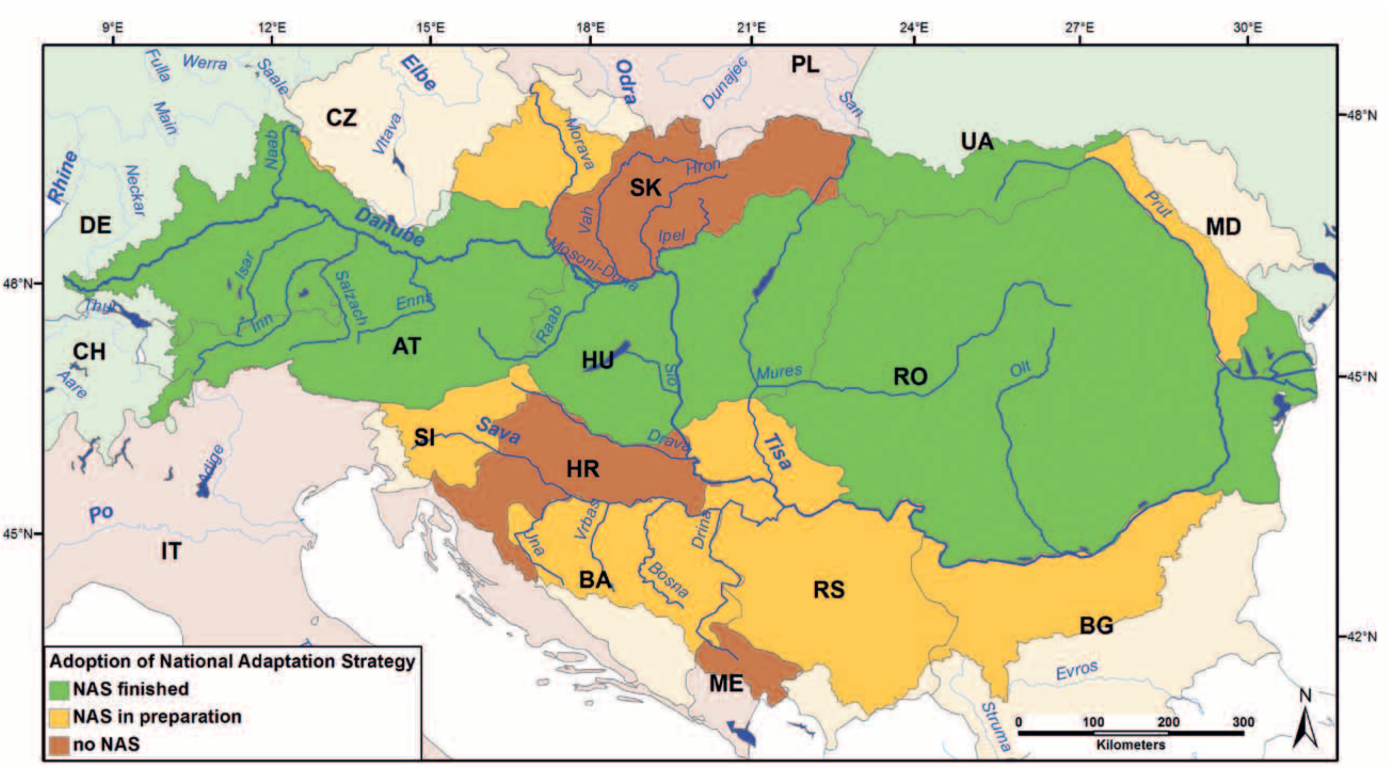
5 *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007L0060:EN:NOT*

In contrast to the WFD, climate change is explicitly included in the Floods Directive. In particular, the preliminary flood risk assessment shall include an assessment of the impacts of climate change on the occurrence of floods. In addition, for the implementation of the Floods Directive, coordination with the implementation of the WFD is required in order to ensure that differing and conflicting interests can be properly balanced and maximum synergies are gained.

2.2 National and international adaptation activities

Besides the EU Water Framework Directive and the EU Floods Directive, several national and international activities are as well of relevance for climate adaptation in the Danube River Basin. National Adaptation Strategies focus on the assessment of the present situation and on the requirements for adaptation to climate change. They include suggested adaptation measures with regard to water-related issues. Figure 3 illustrates the current status of adopted or planned National Adaptation Strategies. Most of the Danube countries have a National Strategy or are preparing one. This reflects the growing recognition of climate change impacts and the rising awareness of the necessity to adapt to climate change.

Overview of the current status of National Adaptation Strategies in the DRB (as of January 2012) *FIGURE 3*



Additionally, National Action Plans for Croatia, Romania and Bulgaria, as well as several national communications under the United Nations Framework Convention on Climate Change (UNFCCC), are important documents to serve, together with the National Adaptation Strategies, as a basis for international coordination within the Danube basin.

At the European level, the most important policy documents on adaptation to climate change for the water sector are the EC White Paper on Adaptation[6], the EU CIS Guidance No. 24[7], and the Blueprint to Safeguard Europe's Water Resources[8], beside the Guidance on Water and Adaptation to Climate Change[9], which was developed in the framework of the United Nations Economic Commission for Europe (UNECE). The European Climate Adaptation Platform (CLIMATE-ADAPT) is currently accessible under the domain name http://climate-adapt.eea.europa.eu (former EU Clearinghouse on adaptation). A short description of the most important documents is given in Table 1.

Important activities addressing the topic of adaptation *TABLE 1*

Document	Description
National communications under the UNFCCC	The national communications (5th or initial)[10] provide an overview of the present and future impacts of climate change and adaptation measures at the country level (and one at EU level).
EU White Paper (2009)	The EU White Paper "Adapting to climate change: Towards an European framework for action" calls for a more strategic approach to climate change adaptation across different sectors and levels of governance: *inter alia*, to promote strategies which increase resilience to climate change e.g. by improving the management of water resources and ecosystems, to deliver adaptation actions for flood risk, water scarcity and drought management and river basin management through catchment-based approaches.
EU CIS Guidance No. 24 (2009)	The EU CIS Guidance document shows ways on how to integrate climate change into the 2nd and 3rd River Basin Management (RBM) cycles of the WFD with a special focus on floods and droughts, and on how to ensure that the River Basin Management Plans (RBMP's) are climate-proofed in 2015.
2012 Blueprint to Safeguard Europe's Water Resources	The overall objective of the Blueprint is to improve EU water policy in order to ensure good quality water, in adequate quantities, for all authorised uses. It will ensure a sustainable balance between water demand and supply, taking into account the needs of both people and the natural ecosystems they depend on. The Blueprint's policy recommendations will be based on the results of four ongoing assessments: 1. analysis of the WFD's river basin management plans (RBMP); 2. review of the 2007 policy on water scarcity and drought; 3. the water's vulnerability to climate change and man-made pressures; and 4. outcome of the fitness check of EU freshwater policy. The 2012 Blueprint will be released by the end of 2012.
CLIMATE-ADAPT	The European Climate Adaptation Platform (http://climate-adapt.eea.europa.eu) provides information on expected climate change, the current and future vulnerability of regions and sectors, national and transnational adaptation strategies, adaptation case studies and potential adaptation options and tools that support adaptation planning.
UNECE Guidance on Water and Adaptation to Climate Change (2009)	The UNECE Guidance aims to support decision makers from the local to the transboundary and international level by offering advice on the challenges caused by climate change to water management and water-related activities and for developing adaptation strategies.

There are also a few additional regional adaptation activities in parts of the Danube River Basin, namely in the sub-basins of the Sava and Tisza rivers, the Danube Delta, the Alpine Space and the Carpathian Region.

6 *European Commission (2009): Adapting to Climate Change: Towards a European framework for action. SEC (2009), Commission Staff Working Document, Impact Assessment, 287, 1-133.*

7 *European Communities (2009): Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 24. River Basin Management in a Changing Climate. Technical Report, Nr. 40.*

8 *European Commission (2012): A Blueprint to Safeguard Europe's Water Resources. http://ec.europa.eu/environment/water/blueprint/index_en.htm: [Accessed 21.01.2013]*

9 *UNECE (2009): Guidance on water and adaptation to climate change. United Nations Publication, Geneva.*

10 Link *to Information on national communications under the UNFCCC: http://unfccc.int/national_reports/annex_i_natcom/submitted_natcom/items/4903.php*

2.3 ICPDR approach towards strategy development

Based on its mandate to develop the 'ICPDR Strategy on Adaptation to Climate Change', the ICPDR decided to nominate Germany to lead the activity within the framework of the ICPDR, with the River Basin Management Expert Group as the responsible ICPDR Expert Group following the issue. In support of the development of the Strategy, additional experts were nominated by the Danube countries, to be involved in and provide expertise during the elaboration process.

In its function as 'Lead Country' on the activity, the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety supported a study with the aim of providing foundations for a common, Danube-wide understanding of the future impacts of climate change on water resources and suitable adaptation measures as a basis for the development of the Danube Climate Adaptation Strategy. The 'Danube Study – Climate Change Adaptation'[11], including the main relevant impacts and fields of action, was developed by the Ludwig-Maximilians-Universitaet Munich (Department of Geography, Prof. W. Mauser) with the involvement of experts and stakeholders from the Danube countries, and was finalised in January 2012 (based on information available until June 2011).

The results of the Study were presented and discussed in the framework of the 'Danube Climate Adaptation Workshop', which was organised in March 2012 in Munich. The discussions and output of the workshop allowed taking the first steps in the development of the Strategy, which was subsequently further developed with the broad participation of relevant ICPDR Expert Groups and Task Groups, including nominated experts and ICPDR Observer Organisations, in 2012.

2.4 General considerations

A basic principle which was followed during the elaboration process was to build the Strategy on the best knowledge available. This was the case for the development of the 'Danube Study – Climate Change Adaptation' in particular, and also for the development of the Strategy in general. By building the Strategy on existing material (including, for example, the EU CIS Guidance Document No. 24[12]), the linkage to ongoing international processes on adaptation, specifically the EU process, is ensured.

The focus of the Strategy is clearly on issues relevant at the Danube basin-wide scale (level A), being in line with the mandate of the ICPDR, while at the same time paying attention to the different levels of river basin management (level A, B and C) as requested by the WFD and EFD. Hence, further detailed planning on adaptation has to take place at the sub-basin, national and/or sub-unit level.

The main objective of the Strategy is to guide the way to fully integrate climate adaptation into the 2nd DRBM Plan and the 1st DFRM Plan. The Strategy therefore does not include a jointly agreed Programme of Measures on adaptation. The 2nd DRBM Plan and the 1st DFRM Plan will include Programmes of Measures which will integrate the issue of climate adaptation. This approach allows to make best use of the management plans required by the WFD and EFD as the key tools for adaptation. Another particular advantage of this approach is that it makes best use of the knowledge and experience already existing in ICPDR Expert and Task Groups, thereby ensuring that the high complexity of the topic will be properly dealt with.

11 Prasch, M., Koch, F., Weidinger, R., Mauser, W. (2012): Danube Study - Climate Change Adaptation. Ludwig-Maximilians-University Munich, Department of Geography. Final Report (available on ICPDR website).

12 European Communities (2009): Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 24. River Basin Management in a Changing Climate. Technical Report, Nr. 40.

SECTION II
Knowledge base

The knowledge about the magnitude of climate change as well as of the uncertainty about the magnitude of the effects of a changing climate is of major importance for managing adaptation to climate change. In order to assess climate change impacts in the Danube River Basin and to identify appropriate adaptation measures, the 'Danube Study – Climate Change Adaptation' analysed ongoing and finalized research and development projects and studies as well as adaptation activities. The study is based on the best knowledge available as recommended in the CIS Guidance Document No. 24. It was broadly discussed at the Danube Climate Adaptation Workshop held in Munich on 29/30 March 2012 and provides the main knowledge base for the elaboration of the adaptation strategy. The study is based on existing information available – no new modelling was carried out.

The following chapters provide information on the main results of the study.
Further detailed information can be obtained directly from the Study.

3 Climate change scenarios for the Danube River Basin

For the assessment of future climate parameters, various global and regional climate models are used. Over the course of time, the models have been further developed in regard to coupled processes between different land surfaces, the atmosphere and oceans. Nevertheless, models are based on simplifications and assumptions. Despite careful validation, climate models sometimes over- or underestimate the investigated parameter compared to observed data. To determine climate change information from a global to a regional or local scale, different downscaling techniques are used. Furthermore, the underlying IPCC SRES[13] emission scenarios reflect only a range of possible developments, so the results of future simulations bear a certain degree of uncertainty.

Most of the future projections analysed within the 'Danube Study – Climate Change Adaptation' are based on the IPCC SRES scenarios A1B and A2. The SRES scenarios cover a wide range of the main driving forces of future emissions as well as demographic, technological and economic developments.

Explanation of IPCC SRES A1B and A2 scenarios *TABLE 2*

A1B: A balanced energy production across all energy sources is reflected in the A1B-scenario embedded in the A1-storyline which describes a future world of very rapid economic growth, a global population that peaks in the middle of the current century, and the rapid introduction of new and more efficient technologies

A2: The A2-storyline describes a very heterogeneous world with a preservation of local identities and a primarily regionally oriented economic and technological development. Hence the global population is continuously increasing. The A2-scenario reflects a future with high emission rates (much higher than in A1B)

The analysis of the future development shows for the climate parameters temperature, precipitation and its extremes different degrees in uncertainty. Projections of temperature values are very reliable due to the unambiguously results of the analysed projects. However, future precipitation patterns are more difficult to simulate, so the projected changes are not as robust as for temperature. The findings often agree in sign of changes but differ in magnitude. In some areas, the results do not agree or are contrary.

Changes are mainly described for 30-year future periods (mostly for 2021-2050 and 2071-2100), but it has to be mentioned that, within these periods, there may be many years where precipitation or temperature values are opposite to how they were anticipated by the general trend, due to the natural variability of the climatic system. In the following, expected changes are described for both: SRES scenario A1B for the periods 2021-2050 and 2071-2100; as well as for the SRES scenario A2 for the periods 2010-2039 and 2049-2060. Furthermore, temperature and precipitation changes are described for meteorological seasons, whereas: spring includes the months March, April and May; summer the months June, July and August; autumn includes September, October, November; and winter the months December, January and February.

There is general agreement that extreme weather events are increasing in most parts of the Danube basin. Generally, however, extreme events, especially heavy rainfall, are very difficult to model and therefore the results are linked with related uncertainties. Projected future changes are often described for different countries. Therefore the examples of expected changes are illustrated on a country-by-country basis from Figure 4 to Figure 7 to follow. Of course, the values do not change abruptly at national borders.

13 SRES means "Special Report on Emissions Scenarios". The so called SRES scenarios cover 40 scenarios for the 4th (2001) and 5th (2007) IPCC report, developed from so called IS92 scenarios of previous IPCC reports. The 40 IPCC SRES scenarios are subdivided into 4 "scenario-families" A1, B1, A2 and B2.

3.1 Air temperature

For the Danube River Basin, an increase of air temperature with a gradient from northwest to southeast, annually and in all seasons, is projected as a main future trend (Figure 4). Particularly the southeastern Danube region is expected to become much warmer than in the last decades. The mean annual temperature increase for the near future period (2021-2050) differs regionally between +0.5°C and +4°C. This tendency might intensify during the second half of the century with values between 2.5°C and 5°C at the end of the century.

While, in the near future period (2021-2050), the seasonal temperature increase might reach values between 0.7°C and 2.1°C, particularly the changes in mean summer temperatures in the period 2071-2100 are more distinct and could reach values of 2.8°C to 6°C. Nevertheless, there are considerable local differences due to climate influencing factors such as altitude, mountainous massifs, seas, lakes and lowlands. However, the general increasing trend is very reliable due to the high correlation of many studies (see Figure 9). In all models the uncertainty is largest for winter.

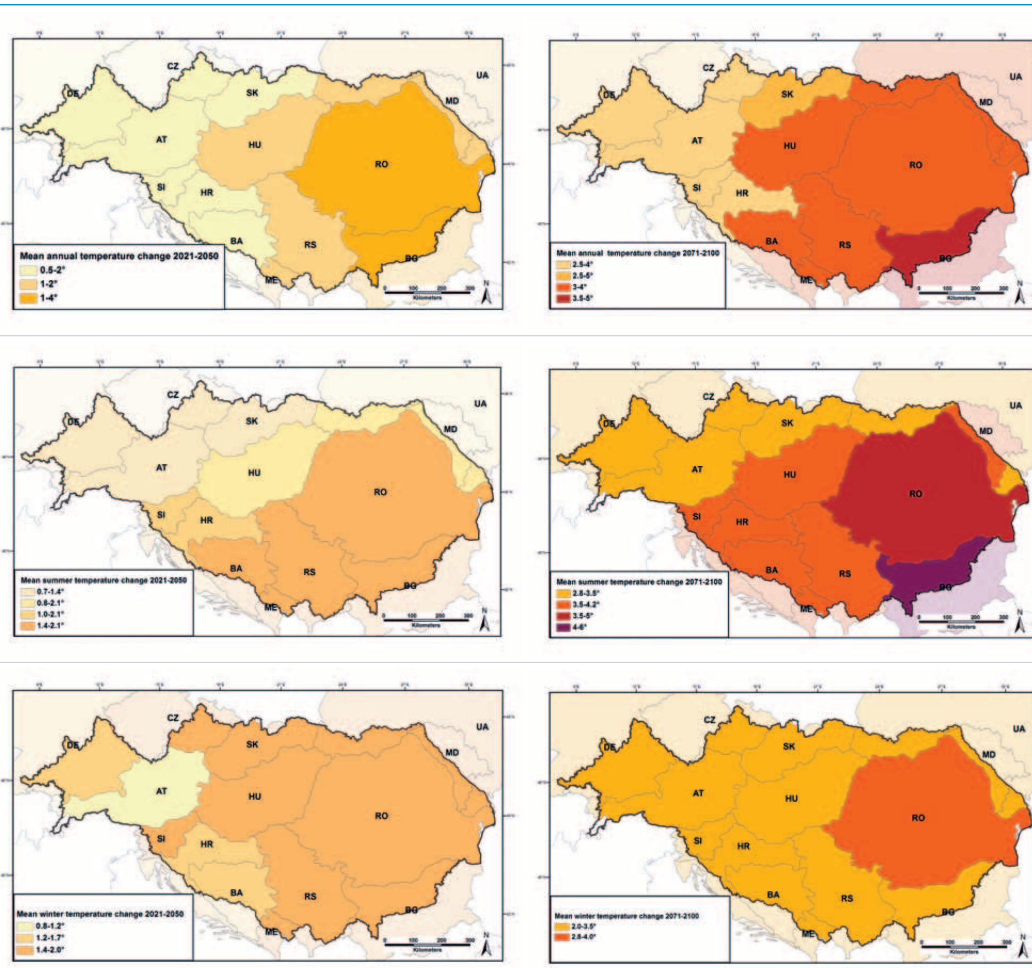
Change of mean annual, summer (JJA) and winter (DJF) temperature in the Danube River Basin for 2021-2050 and 2071-2100 according to A1B scenario of different model results *FIGURE 4*

2021 - 2050 | 2071 - 2100

Annual mean temperature changes

Summer mean temperature changes

Winter mean temperature changes



3.2 Precipitation

The Danube River Basin is located in the transition zone between expected increasing (in Northern Europe) and decreasing (in Southern Europe) future precipitation. This general trend is more obvious in the second half of the century as illustrated for the Danube basin in Figure 5. Although the mean annual values in many countries will probably remain almost constant, a tendency for the next decades toward more precipitation (than in the last decades) in the northern parts of the basin and less precipitation in the southern parts is apparent.

The Alpine Space is divided into a wetter north and a drier south, especially the southeastern part of Austria is likely to become drier. Furthermore, the distribution pattern for Romania is divided into a northern region (higher elevations in the Carpathian Mountains) with more precipitation and a southern region (lowlands) with less precipitation than today.

According to the analysed projects, large regional and seasonal changes in future precipitation are projected for the 21st century. There is less information and no clear tendencies for spring and autumn, but multiple scenario results show future decreasing trends for summer (on average app. -15%; in some parts up to -30%) and a tendency for increasing winter precipitation (app. +5 to +20%; in some parts up to +35%) with, however, a high variability. The tendency for drier summers strengthens during the course of the century as shown in Figure 6. The results for the future trend of increasing winter precipitation are illustrated in Figure 7.

Naturally there are regionally opposing trends (e.g. in southern parts of the Alps, including Slovenia, where decreasing values for winter are simulated). In the Middle Danube Basin, especially in Hungary, a reversal of seasonal precipitation distribution is often indicated in research results. This means that, currently, most precipitation falls during summer and least during winter. The projected changes anticipate that this pattern will significantly change in the future with a more uniform precipitation distribution over the Upper and Middle Danube Basin.

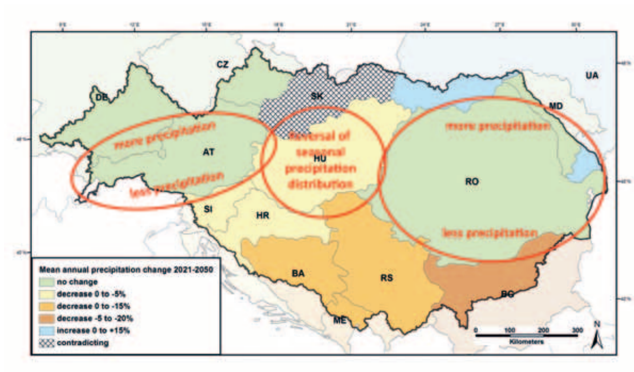
Because the general trend is consistent in most simulations, the certainty-category for precipitation is high (see Figure 8); it is less robust and reliable, however, compared with that for air temperature. Different models produce partly contrasting patterns of the spatial distribution of precipitation and there are many quantitative uncertainties in the changes for both mean and extreme precipitation amounts.

Higher temperatures in winter affect the cryosphere. Instead of snow, it might rain more often and, together with an earlier beginning of snow melt, the snow cover is expected to decrease and the snow season thus becomes shorter in all altitudes. However, some findings for mountainous areas state no trend or even a slight increase of snow fall due to a possible increase in winter precipitation. Glaciers show a significant retreat in the DRB. Climate change leads to the total disappearance of glaciers in all mountainous areas of the Middle Danube River Basin (MDRB). In the alpine part of the Upper Danube River Basin (UDRB), only a few small glaciers will remain in the far future.

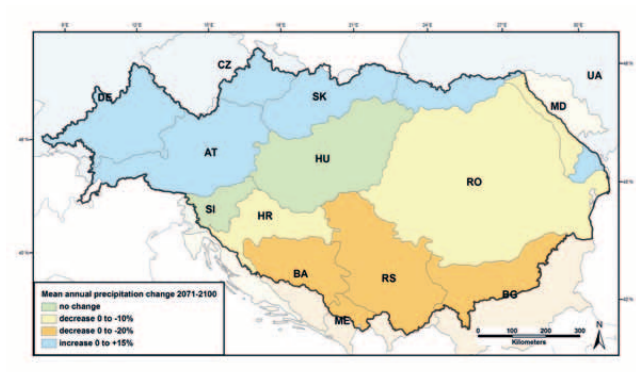
Change of mean annual precipitation in the Danube River Basin for the periods 2021-2050 and 2071-2100 according to A1B scenario of different model results

FIGURE 5

2021 - 2050



2071 - 2100



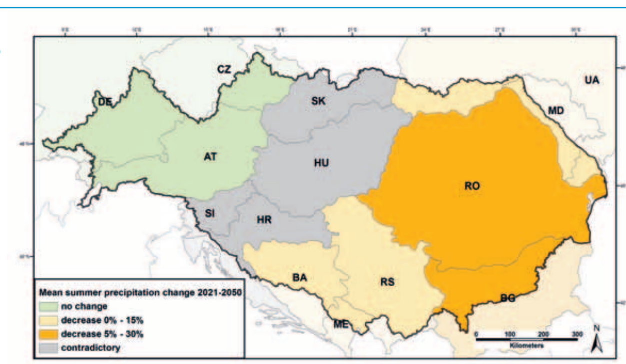
Change of summer (JJA) mean precipitation in the Danube River Basin for different periods according to A1B and A2 scenarios of different model results

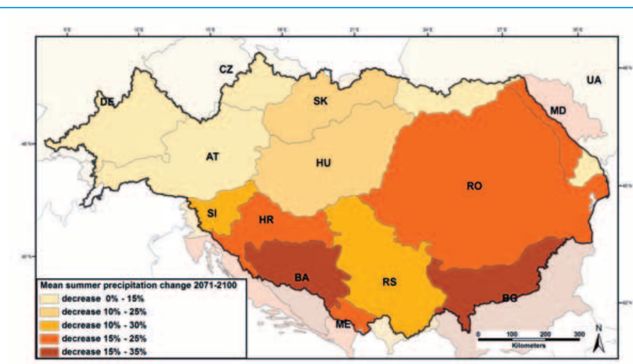
FIGURE 6

2021 - 2050

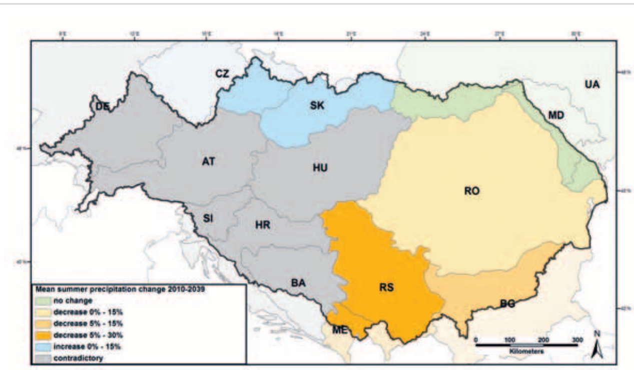
2071 - 2100

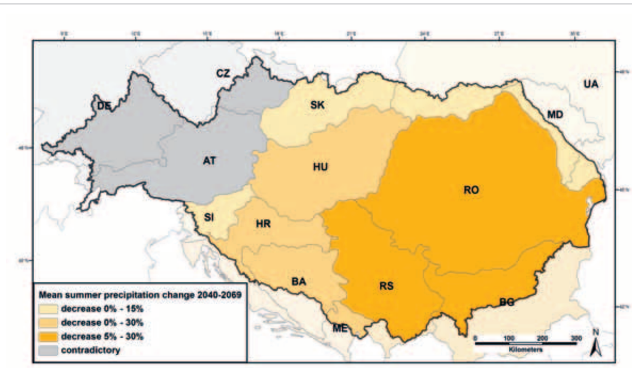
A1B





A2



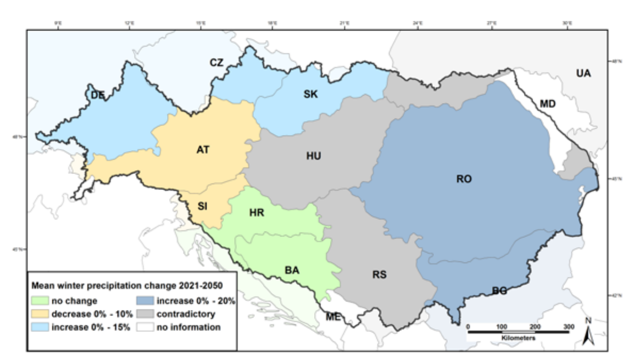


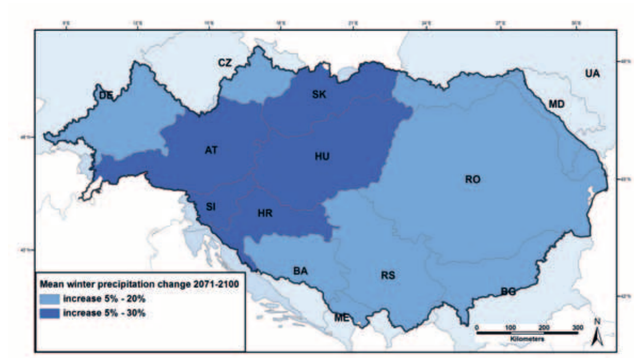
Change of winter (DJF) mean precipitation in the Danube River Basin for different periods according to A1B and A2 scenarios of different model results

FIGURE 7

2021 - 2050 | **2071 - 2100**

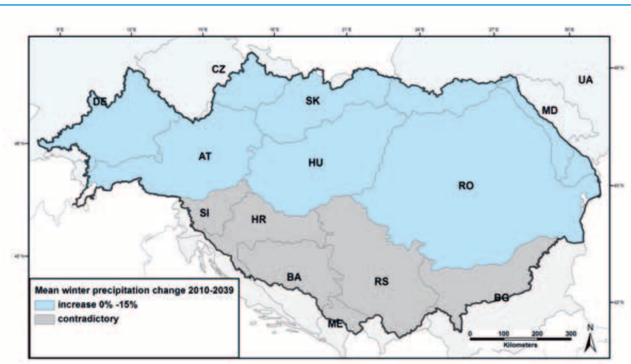
A1B

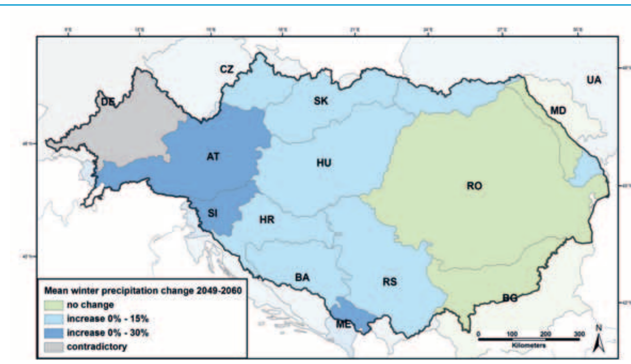




2021 - 2039 | **2049 - 2060**

A2





3.3 Extreme weather events

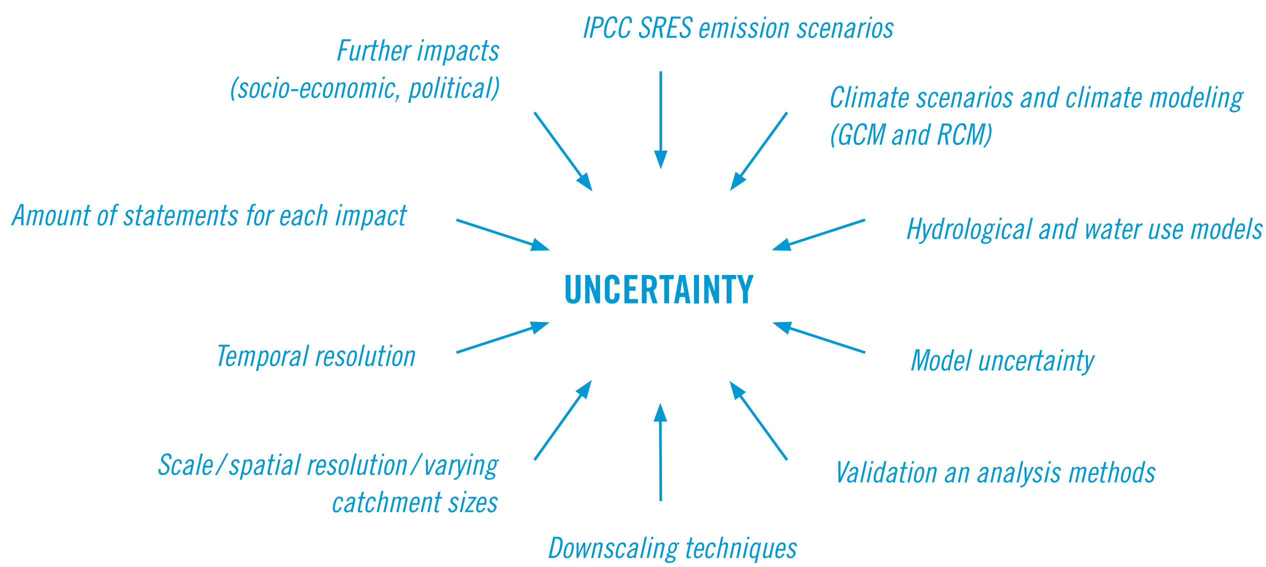
A future increase in extreme weather events is expected for the whole DRB. The simulations show both a future increase in the intensity and frequency of dry spells, hot days and heat waves, as well as local and regional increases in heavy rainfall, although the latter is uncertain in spatial and temporal allocation. For the Upper Danube Basin, an increased risk of storm-related heavy precipitation with high wind speeds is assumed. For the Middle Danube Basin, it is of interest that the occurrence of extreme precipitation days will be intensified in winter and reduced in summer. Due to the warming trends for the whole basin, fewer frost days are expected in winter.

4 Water-related impacts of climate change in the DRB

4.1 Uncertainty

Many different factors are influencing the certainty of the statements about climate projections and climate change-related impacts on the water sector analysed in the 'Danube Study – Climate Change Adaptation'. Figure 8 summarizes the main factors, which lead to different levels of uncertainty for these statements. They are further described in detail, more or less clockwise beginning at twelve.

Main factors influencing uncertainty in climate change analysis *FIGURE 8*



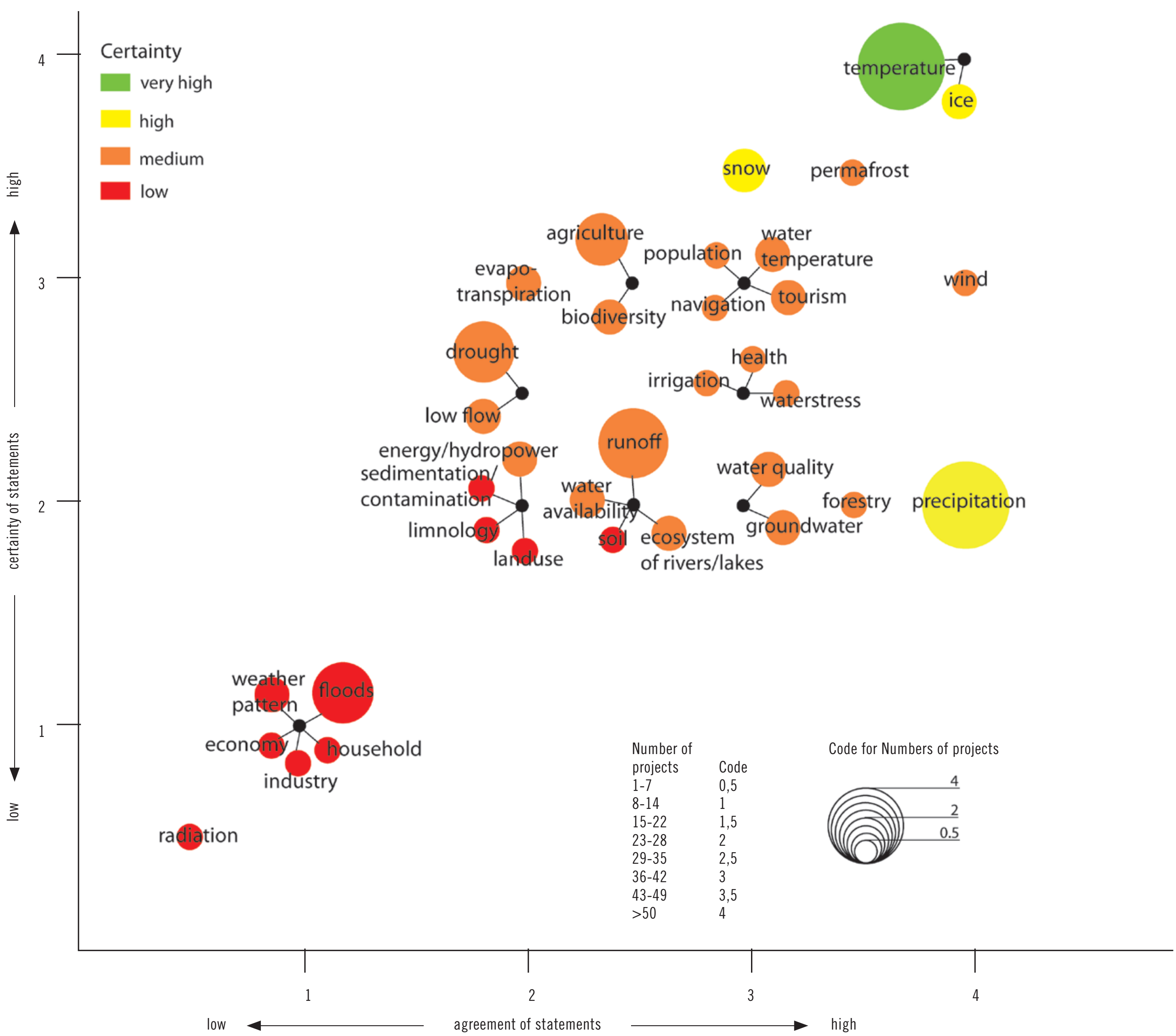
For climate change projections, different possible future assumptions (*inter alia*, for the emissions of greenhouse gases and socio-economic development), reflected by various IPCC SRES scenarios, serve as a basis (see Chapter 3). However, for the same SRES scenario, the outcomes of different climate models are diverse because the models represent the climate process in different ways. Generally, each climate and hydrological projection is subject to limitations in its ability to model the climate and water-related system. Even if some projects use the same Global Circulation Model (GCM), they can still differ in further applications such as regional modelling and downscaling techniques. In the Danube countries, different Regional Climate Models (RCM) and, in several catchment areas, different hydrological models are used. Only a few projects use a water-use model, which can compute both water use and availability on a river basin scale.

Different methods are applied for validation and analysis of the projections. Downscaling techniques are used to attain climate change information from a global to a regional and local scale. In addition to these different methods, the findings often differ widely in relation to space and time – in the end, therefore, they can not be simply compared and summarized. For each issue (see Chapter 4.2), a different number of projects and studies are available. For some impacts, only very few statements are available, whereas for others, many studies are analysed. But a high number of available studies does not automatically imply a high agreement of their findings. Finally, climate change is accompanied by other influences such as political or socio-economic impacts.

To give "uncertainty" respectively "certainty" a tangible form, three variables are used in the Study to determine a certainty category for climate parameters and impacts: 1. certainty of statements; 2. level of agreement between different statements; and 3. number of analysed studies. The first and second variables are assigned to one of eight values within the range 0.5 and 4. The third variable is a real number, coded in eight categories. Further details are described in the 'Danube Study'.

Figure 9 gives a pragmatic overview of the certainty of each climate-related impact in the Danube River Basin due to the analysis of projected changes. If the number of the projects considering one special impact is large, and the agreement and certainty assessment is high, the certainty category indicates a high overall certainty, such as for temperature. However, if the number of projects is high, but the agreement or the certainty assessment of the statements and results is low, the certainty category shows a medium-ranged overall certainty.

Overview of certainty for the impacts in the Danube River Basin due to projected climate changes *FIGURE 9*



The certainty of the projections for temperature and precipitation are high and, due to the above mentioned factors, the certainty of water- and temperature-related impacts show mostly a medium certainty. Some tend to a higher category, such as for agriculture, runoff and drought. For the most analysed sectors, the certainty category indicates that changes are to be highly expected and that adaptation measures should be required now in water management.

The overall level of certainty should be taken into account in the development of future adaptation measures. A high level of certainty may allow for the preparation of adaptation measures at an early stage and/or with more detail, whereas a low level of certainty may lead to more general types of measures (e.g. no-regret measures or win-win solutions).

Of high interest in many sectors are future flood events as well as droughts and low flow situations. Therefore, for these phenomena, the classification and hence the interpretation of the certainty category are explained in more detail. As can be extracted from Chapter 2.2, flood risk management is often addressed by adaptation activities. However, the certainty of flood projections is low. This is because, within the analysed projects (number=33), the agreement of statements is very weak (see Figure 9). The findings on the future development of flood frequency, especially for the one-hundred-year flood (HQ_{100}), differ widely. The certainty of the statement is rated as low (Code 1), because flood events are triggered by many factors such as temperature, precipitation, atmospheric conditions, runoff, routing and snow melt. The future development of these factors is not fully clear. Additionally, precipitation-driven flood events are mainly short-term events that occur locally. As a result, floods are difficult to simulate by models, especially for small catchment areas which have poor spatial and temporal resolution for precipitation data. Improvements such as the implementation of “rain-on-snow events” and the capture of soil water content by models are important for more reliable statements.

Despite the fact that fewer projects were analysed for droughts, and especially for low flow situations, their certainty category (namely medium) is higher than for floods. This is because their model results were mostly consistent (although alpine areas observed some few contradictory findings (agreement Code 2). Droughts and low flow situations are expected to increase, especially in summer, and in the southeastern parts of the DRB.. Although the simulation of extreme events is generally less certain than those for average situations (e.g. mean annual precipitation), the modelling of medium- to long-term events such as droughts is more certain than short-term events such as floods due to the temporal resolution (certainty Code 2.5).

Perspectives of future uncertainty reduction through science

Not all of the factors influencing uncertainty are determined by a current lack of scientific knowledge. Natural short-term weather fluctuations, as well as the uncertainty about assumed future greenhouse gas emission scenarios, create ambiguities which cannot be reduced through an increase of scientific knowledge. Therefore, the discussion on the formulation and choice of suitable scenarios should be segregated from the uncertainty discussion and treated independently.

Science can, however, further reduce the uncertainty of the results of a scenario simulation by improving the skills of global and regional climate modelling as well as of the diverse climate impact models over the next decades. This will most likely be achieved by replacing current model parameterizations, which are based on past statistical relations, by first order science principles found in current climate and impact models. In the meantime, considerable uncertainties can be expected to prevail. This calls for evaluating and quantifying these uncertainties thoroughly and finding scalable adaptation measures that can be adjusted as new evidence arises.

4.2 Overview of the main impacts

Alongside the already mentioned regional and seasonal temperature and precipitation changes expected in the course of this century, the direct and indirect effects of these changes are of essential interest. This includes impacts on different fields related to water availability, extreme hydrological events, water quality, water and land use, and ecology. Despite the high heterogeneity and the frequent low comparability of the project results, the expectations for future climate conditions and their related impacts show mostly similar trends. Hence, only qualitative information can be given for the different impact fields instead of quantitative or probabilistic statements. For the main fields, the expected impacts are listed in the following tables.

Expected impacts on water availability *TABLE 3*

Water availability	
For the next decades, a decrease in water availability for the southern and eastern parts of the DRB is indicated, whereas in the northern and western parts no trend or even a slight increase is projected. Changes in water availability can highly differ locally or regionally. This may result in medium to severe water stress in the MDRB, and in severe water stress in the Lower Danube River Basin (LDRB). Water stress is expected to remain low in the UDRB because of generally high water availability there.	
Runoff	Runoff seasonality shows a future increase of the mean discharge in winter and a decrease in summer for the entire DRB. Seasonal changes may differ locally. The main causes are changes in precipitation and in snow (and ice) storage. A decrease in snow precipitation, and accordingly in snow cover, together with an earlier snow melt, causes a shorter snow season in all altitudes and will in turn lead to a shift of the runoff regime. In the head watersheds of the Alps and the Carpathian Range, this will cause a shift in peak runoff from early summer to spring, with an increasing risk of floods also in the surrounding lowlands. An increase in glacier melt has relevance only for the summer runoff situation in the head watersheds and has almost no influence on the runoff regime of larger river systems.
Snow/Ice/ Permafrost	Decrease of water storage in form of snow and ice. A further retreat of permafrost in mountainous regions will lead to a higher frequency of rock falls, other natural hazards and more sedimentation in rivers.
Groundwater	A general decline in groundwater storage and recharge for Central and Eastern Europe, especially in summer, is assumed. Besides shortages in water availability, a decline in groundwater recharge could also lead to negative effects for groundwater quality. Additionally, a possible increase in irrigation using groundwater resources could intensify the decline. Regarding regional differences, a pronounced decline is particularly indicated for the Hungarian Great Plain Area, which was monitored already in the past. For some alpine regions, however, a local increase in groundwater storage is likely to occur.
Evaporation	Mean annual potential evaporation will increase due to warmer temperatures in all regions of the DRB, especially in summer, which can even lead to an acceleration of water stress. In regions with low water availability, such as the southeastern parts of the DRB, actual evaporation will decrease, especially during dry periods, because less water is available to evaporate or transpire through plants.

Expected impacts on extreme hydrological events *TABLE 4*

Extreme hydrological events	
In general, it is less reliable to model the future development of extreme hydrological events such as floods than changes in the average water balance. This is especially true at the local scale. The assessment of future floods therefore includes high uncertainty. Extreme weather events sometimes have a significant impact on hydrology. Therefore, torrential rainfall may cause a flash flood and a dry and hot period may cause a drought situation. Since extreme weather events are expected to become more frequent and intense, extreme hydrological events are expected to follow. The main causes are the expected future changes of temperature and precipitation patterns. Anthropogenic developments (e.g. land use changes, silting up of flood plains, and overgrowth of flood channels by vegetation or river regulations) will influence future flood appearances.	
Drought/ Low flow/ Water scarcity	Within the DRB, drought and low flow events, as well as water scarcity situations, are likely to become more intense, longer and more frequent. The frequency could increase especially for moderate and severe events. Due to less precipitation in summer, these extreme events will occur more frequently in summer than in winter. In some parts of the DRB, the drought risk is expected to increase drastically in the future, leading to possible economic loss, potential for water conflicts and water use restrictions. The Carpathian Area, particularly the southern parts of Hungary and Romania, as well as the Republic of Serbia, Bulgaria and the region of the Danube Delta, are likely to face severe droughts and water stress resulting in water shortages. In alpine areas (e.g. some parts of Austria), no clear trend or even a slight improvement of the mean annual low flow and drought situations were identified. Therefore, alpine head watersheds remain important for downstream areas during drought periods. The future low flow situation also depends on changes in water use, which could worsen or improve the general trend.
Flood	There is no clear tendency in the development of future flood events for the DRB as a whole. Within the basin, there are different local tendencies, especially for the development of extreme flood events. An increase in flood intensity and frequency is likely to occur with emphasis on small and medium flood events, especially in alpine regions in late winter/spring, triggered by changes in winter precipitation and snow storage.
Flash flood	Short-term flood events may occur more frequently. For small catchments, an increase in flash floods due to more extreme weather events (torrential rainfall) is expected (e.g. in the Carpathian Range or the Sava and Tisza headwaters).

Expected impacts on water quality *TABLE 5*

Water quality	
Following the future increase in air temperature, water temperature will most likely increase in the DRB. Due to changes to all temperature-dependent chemical and biological processes, as well as increasing flood and drought events, the pressure on water quality in rivers and lakes increases.	
Water temperature	Exact numbers differ regionally and locally, but 1-2 K are often mentioned, particularly of surface waters and groundwater in summer. Freezing periods in winter are most likely reduced and the ice cover on lakes and rivers may decrease.
Water quality	Water quality is expected to be reduced (e.g. by a decreasing oxygen concentration in rivers, aquifers and lakes). Increased algal blooms may appear with higher water temperatures. More frequent flooding and flash floods can cause a higher mobility of particle-associated pollution, and changes of the redox balance of inorganic compounds can cause the release of organic colloids. After long droughts, preferential flow paths are of particular relevance in groundwater protection zones given the fact that pollutants can pass rapidly along them and almost unimpeded into groundwater[14].

14 Preferential flow: Transfer of water and dissolved substances through the soil into the groundwater along root traces, wormholes and drying cracks.

Expected impacts on water use / land use *TABLE 6*

Water use / Land use	
Climate change may affect all types of land use. An intensification of extreme events, such as floods and droughts, leads to high impacts for agriculture, forestry and industry, as well as built-up areas and infrastructure. As a consequence of decreasing water availability, a shortcoming in water supply is expected. An increased risk of conflicts over water use can occur in the event that no adequate adaptation measures are taken. Possible consequences are difficulties in water supply with an increased risk of water shortages and an over-exploitation of aquifers in the future. Besides climate change impacts, future water demand is also triggered by anthropogenic impacts, political regulations and restrictions, and new technologies.	
Water supply	An assumed general increase in water demand for households, industry and agriculture, together with pronounced water scarcity during summer in the Lower and Middle Danube Basin and in some areas of the UDRB, is likely to lead to high water stress. Industrial production losses are possible during droughts and hot summers due to scarce water supply, as well as increased difficulties in accessing water resources and higher costs for water resource use.
Water demand	Due to a warmer climate, increased water demand by, and water withdrawal for, agriculture, industry, energy and human consumption is probable, especially in the southeast DRB and in the hot season. This includes increased water use, for example, for garden watering and field irrigation, household showers and cooling water for industrial plants.
Agriculture	Because of warmer and drier summers, water demand for livestock and irrigation can become higher. Additionally, the appearance and development of pests and diseases can increase. The UDRB may benefit from a longer growing period, but in the MDRB, and especially in the LRDB, a shortening of the growing season with yield losses is expected. Due to more unstable weather conditions, the inter-annual variability of crop yields increases, so that farmers will have higher economic risks.
Irrigation	Irrigation for agricultural purposes is likely to increase in the entire DRB, especially in the southeastern parts, due to an expected expansion of droughts during the growing season in the future. An increase may deteriorate the ecological and chemical balance of freshwater bodies and could lead to an increase of contaminated surface and groundwater bodies after enhanced agricultural use.
Navigation	More frequent limited or impassable navigation conditions are expected due to more frequent extreme water levels and unstable conditions, especially on routes comprising free-flowing river reaches. Higher future temperatures in winter have a positive effect because of less frost and icing. Low water levels lead to reduced cargo and limited navigability. This is particularly true for the MDRB countries Slovakia and Hungary, especially in summer for the hot lowlands with less precipitation in future. The development of navigability in the MDRB also depends on climate change impacts in the upper area. For the UDRB, a significant reduction of the minimal low water level, and only little influence for shipping due to future high water projections, is expected.
Hydropower	Future mean annual and mean summer hydroelectric power generation is likely to decrease in the DRB, although increases can occur in winter due to changes in water availability. However, the degree of change is expected to differ regionally and locally, and depends, *inter alia*, on the type and strategic plans of each hydropower station. The decline of the mean annual and mean summer production values can be especially pronounced in the southeastern parts of the DRB. Particularly in mountain areas, a possible seasonal shift due to changes in precipitation and snow cover with a more balanced production over the year is expected.
Thermal electricity production	Possible temperature loads may increase and become problematic in the future. Thermal power stations using cooling water are seriously affected if water becomes warmer and additionally the amount of available water decreases.
Forestry	A lower productivity and health status of forests due to an increase in droughts is possible, especially in the southeast. However, due to higher annual temperatures, the length of the growing season may be extended and elevated atmospheric CO_2 concentrations can have a fertilising effect. Changes in the distribution, density and biodiversity of forests are also assumed. Forests may be impacted by an increasing risk of damage from forest-weakening pests (e.g. bark beetle), storms and forest fires. Cold- and snow-related damages are likely to become less common, while an increase in spring frost damage is possible.

Expected impacts on ecology *TABLE 7*

Ecology	
An increase in air and water temperature, combined with changes in precipitation, water availability, water quality and increasing extreme events, such as floods, low flows and droughts, may lead to changes to ecosystems, life cycles, and biodiversity in the DRB in the long-term. The habitats and ecosystems in the southeastern region of the DRB and in the Hungarian Great Plain area are especially likely to become drier and more fire accidents might occur.	
Biodiversity	Migration patterns are expected to expand northeastward and to higher altitudes, whereby a rearrangement of biotic communities and food webs, and an earlier onset of life cycles, could take place. Certain species will likely face extinction. While species expected to disappear are mainly native, invasive species may increase.
Ecosystems	Higher stress for aquatic ecosystems, predominantly for littoral communities and fish, may occur, especially in the MDRB and LDRB. Shifts of and changes to aquatic and terrestrial flora and fauna are expected. Some aquatic systems show a higher risk of algal blooms and eutrophication, indicating an endangerment of lakes and wetlands.
Soils/Erosion	Nearly all regions of the DRB show a possible decrease of soil water content. Longer dry soil periods are predicted, especially for the MDRB and LDRB regions during summer droughts. Thereafter, soil degradation is also possible in these regions. Changes in precipitation patterns and an increase in torrential rain and flash flood events can lead to more intense soil erosion. An increase in soil temperature especially affects physical, chemical and biological processes occurring in top soil layers. Sedimentation in the river system is likely to increase due to more extreme events and permafrost thawing.
Limnology	The water temperature of the top lake layer will increase remarkably. This could lead to changes to lake stratification and energy balance. A decrease in lake levels is possible, especially in summer.
Marine coastal zones	Increasing sea surface temperatures could lead, for example, to a redistribution and losses of marine organisms, an increase of invasive species and an increase in toxic bloom events. Rising sea levels could trigger coastal erosion with damage to buildings and a retreat of the inland coast, as already monitored in the Danube Delta and the Romanian coastline of the Black Sea. Higher sea levels will likely increase the salinization of estuaries and land aquifers with saltwater intrusions, and will reduce the coastal protection of dams and quay walls.

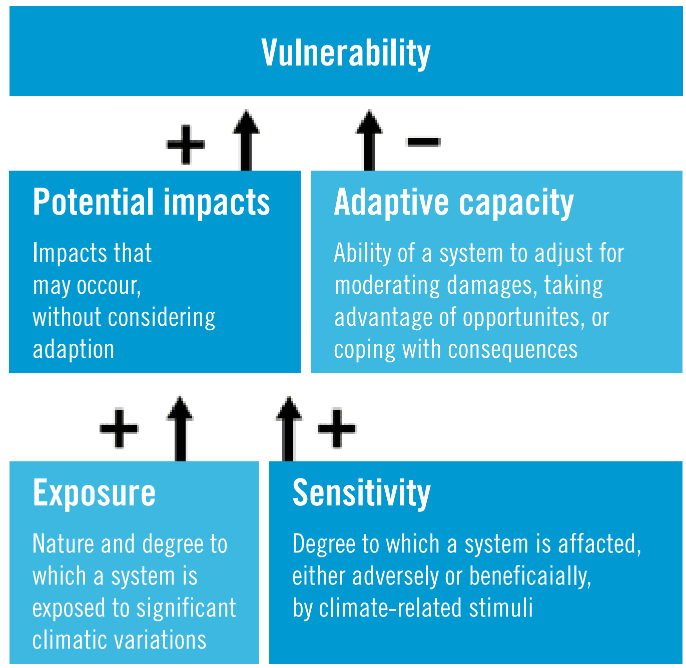
5 Vulnerability

5.1 The IPCC concept of vulnerability, the challenges and the added value of a vulnerability assessment

In the context of climate change the commonly used concept of *vulnerability* is the definition given by the IPCC. It defines vulnerability to climate change as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC 2007).

Following this definition, a vulnerability assessment includes the character, magnitude and rate of climate change and climatic variations to which a system is exposed (*exposure*), the system *sensitivity*, and its *adaptive capacity* (IPCC, 2007)[15].

Figure 10: Key factors of vulnerability[16]



The methodological challenge for an assessment that aims at estimating future vulnerability to climate-related impacts (e.g. for 2050) is to 'foresee' the future system, estimate the sensitivity of this future system and include the adaptive capacity of that system. The description of potential future climate change conditions (exposure) is usually not the bottleneck since data is available from scenarios and models.

Key terms (following the IPCC's definition) associated with the topic of adaptation *TABLE 8*

Definition of keywords	
Vulnerability	The extent to which a system or actor is susceptible to, or incapable of coping with, the detrimental consequences of climate change, including climate variability and extremes. Vulnerability depends on the character, magnitude, pace and variability of the climatic change to which the system is exposed, as well as the sensitivity and adaptive capacity of the system or actor.
Exposure	The degree of climate stress upon a particular unit or system; it may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events.
Sensitivity	The degree to which a system or actor is either adversely or positively influenced by climate variability or climate changes.
Adaptive capacity	The capabilities, resources or institutional capacities of systems, organisations or (individual) actors that enable them to adapt to climatic conditions that have been altered, or will alter in the future, and their possible impacts. Adaptive capacity includes the capacity to take effective adaptation measures and, by these means, to reduce potential damages, take advantage of opportunities or cope with consequences, mainly by reducing sensitivity by adaptation measures. To estimate adaptive capacity, socio-economic conditions and future developments need to be investigated, which is often performed through scenarios and expert judgment.

15 IPCC, 2007, Climate Change 2007: Climate Change Impacts, Adaptation, and Vulnerability, Cambridge University Press, Cambridge
16 http://www.cifor.org/fileadmin/subsites/cobam/images/cobam-e5.gif

The added value of an encompassing vulnerability assessment – depending on its spatial and temporal scope – is that it can help to determine specific regional or sectoral hot spots of vulnerability, and to design suitable adaptation measures. In addition, such a vulnerability assessment enables a comparison and thus a prioritisation of adaptation needs and potentials and allows for a more informed or strategic allocation of resources. However, it must be clear that this assessment approach is complex and time- and resource-intense.

To create awareness for adaptation needs and to come to a common evidence base, especially at an early stage of the adaptation process, a helpful first step is usually the development of a less complex impact analysis which does not yet consider socio-economic changes or adaptation efforts.

5.2 Approach for the Danube River Basin

There is currently no consistent and homogenous vulnerability assessment, neither qualitative (descriptive) nor quantitative (based on indicators), which exists for the Danube River Basin as a whole. In Germany (2005) and Austria (2010), qualitative or semi-quantitative vulnerability assessments have been conducted. Quantitative assessments have been carried out within INTERREG-projects or European research projects mostly covering only parts of the Danube River Basin.

The most comprehensive studies covering larger parts of the Danube River Basin are the ESPON Climate[17] and the ClimWatAdapt[18] projects. Both studies have been analysed as part of the 'Danube Study – Climate Change Adaptation' and their results have been integrated into the overview given in Chapter 4. As both studies cover larger parts of Europe, they are not normalized for the Danube River Basin. Thus an extraction of results for the Danube River Basin needs to be interpreted with care.

ESPON Climate and ClimWatAdapt projects *TABLE 9*

ESPON Climate covers the European Union territory of the Danube River Basin. The results of ESPON Climate for southeast Europe show "hot spots" in regards to flooding for Hungary and Slovenia. In other regions of the Danube River Basin, decreasing precipitation may even lead to decreases in flood-related impacts. Environmental and economic impacts due to a hotter and drier climate are expected to be medium to high in most of southeast Europe. In these regions, the adaptive capacity was estimated to be rather low, thus resulting in high levels of vulnerability.

ClimWatAdapt covers the whole Danube River Basin. It focuses on river floods, water scarcity and droughts. In general it shows that, in the future, population numbers endangered by floods vary largely between the regions. The highest potential for health and economic damage is expected in Bosnia and Herzegovina. Annual and summer water stress will mainly influence Serbia, Romania and Bulgaria, due to an expected increase in withdrawals, which can be counteracted by sustainable water management. Otherwise, water stress will aggravate the competition for water between households, tourism, industry, agriculture and nature.

To facilitate the basin-wide coordination of adaptation measures and their prioritisation, a spatially detailed, consistent and homogeneous (quantitative or semi-quantitative) vulnerability assessment for the Danube River Basin would be a helpful instrument and may be a future step in the basin-wide adaptation process. However, for the preparation of the 2nd DRBM Plan and 1st DFRM Plan, it does not seem to be a feasible option, taking into account the necessary resource input and expected added value.

As a first step towards a vulnerability assessment, the existing impact analysis (see Chapter 4) is well set to create a common understanding and knowledge base, and to raise awareness about current and future challenges connected with climate variability and change. In addition, information on the water-related effects of climate variability sourced from national climate adaptation strategies, and the results of national vulnerability assessments, should be taken into consideration by the relevant ICPDR Expert Groups and Task Groups during the preparation of the 2nd DRBM Plan and the 1st DFRM Plan.

17 *Greiving, S. et al. (2011): ESPON CLIMATE - Climate Change and Territorial Effects on Regions and Local Economies. Applied Research Project 2013/1/4. Final Report. Dortmund. Available at:* http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/climate.html

18 *Flörke, Martina, Florian Wimmer, Cornelius Laaser, Rodrigo Vidaurre, Jenny Tröltzsch, Thomas Dworak, Natasha Marinova, et al. 2011. Climate Adaptation – modelling water scenarios and sectoral impacts. Final Report. Center for Environmental Systems Research (CERS) in cooperation with Ecologic, Alterra and CMCC. Available at:* http://www.climwatadapt.eu/

6 Overview of possible adaptation measures

Following the UNECE Guidance[19], climate change impacts on water resources should always be considered together with other pressures or stressors, such as population growth or changing consumption patterns, when planning adaptation measures. As a result, adaptation measures with respect to climate change can often build on planned or already implemented water management measures. Adaptation planning in general should consider and prevent, possible conflicts and provide adequate tradeoffs.

Although the statements on climate change bear a certain degree of uncertainty, adaptation should start now with a priority on win-win, no-regret and low-regret measures which are flexible enough for various conditions. The adaptive approaches within the management framework also require flexibility so they can be modified if new information or understandings become available. This way of working has the benefit of increasing resilience and decreasing vulnerability for the whole Danube ecosystem. For a common understanding of some keywords, definitions are provided in Table 10.

Definition of keywords *TABLE 10*

Adaptation	Adaptation refers to actions that people take in response to, or in anticipation of, projected or actual changes in climate, to reduce adverse impacts or take advantage of the opportunities posed by climate change.
Mitigation	Mitigation refers to actions taken to prevent, reduce or slow climate change, through slowing or stopping the build-up of greenhouse gases in the atmosphere.
Win-win measures	Cost-effective adaptation measures that minimize climate risks or increase adaptive capacity, and which also have other social, environmental or economic benefits; win-win options are often associated with those measures or activities that address climate impacts and also contribute to climate change mitigation or meet other social and environmental objectives.
No-regret measures	Cost-effective adaptation measures that are worthwhile (i.e. they bring net socio-economic benefits) whatever the extent of future climate change is; they include measures which are justified (cost-effective) under current climate conditions (including those addressing its variability and extremes) and are also consistent with addressing risks associated with projected climate changes.
Low-regret measures	Adaptation measures where the associated costs are relatively low and where the benefits, although mainly accrued under projected future climate change, may be relatively large.
Climate-proof	Activities to increase the resistance and resilience of the policies, plans and programs that will be directly or indirectly affected by the impacts of climate change, acknowledging the new conditions where the baseline is inherently unstable and changing, and including climate protection aims.
Resilience	The resilience of a natural system is its capacity to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient system can withstand shocks such as extreme events and rebuild itself. When a system loses resilience, it becomes vulnerable to changes that previously could be absorbed. In a vulnerable system, even small changes may be devastating. Even in the absence of disturbance, gradually changing conditions such as climate, land use and policies can surpass threshold levels, triggering an abrupt system response. Therefore, managing resilience enhances the likelihood of a sustainable generation of ecosystem services benefiting humans in changing environments where the future is unpredictable and changes are likely. [20] [21] [22]
Improvement of resilience	Improvement of resilience involves increasing the ability of a system to withstand shocks and surprises and to revitalize itself if damaged. An integrated adaptive ecosystem management approach that increases ecosystem stability can improve the resilience of the environment and reduce vulnerability to improve the well-being of societies and ecosystems dependent on natural resources. Flexible sustainable decision-making processes that can accept new information, and that can be modified on the basis of this information, are also important elements in building and/or improving resilience.

19 UNECE (2009): Guidance on water and adaptation to climate change. United Nations Publication, Geneva.

The following is an overview of possible adaptation measures. They are classified into five different categories following the UNECE[20] and EEA[21]: preparation measures, ecosystem-based measures, behavioural/managerial measures, technological measures and policy approaches.

Preparation measures aim to support planning processes. This includes monitoring, evaluations of changes, identification of risk areas, elaboration of warning systems and emergency plans and the support of further research where needed.

Ecosystem-based measures aim to reduce the negative effects of a changing climate by enhancing the capacity of the ecosystem to adapt to different impacts. These measures help to conserve or restore ecosystems. Healthy ecosystems can thus contribute to increase resilience to slow changes such as increasing summer temperatures or sudden impacts such as floods.

Behavioural and managerial measures aim to raise awareness about possible future conditions, and to support sustainable management with a focus on the efficient use of water and conservation of good water quality. This includes, *inter alia*, the elaboration of risk management plans for water scarcity and the propagation of best practices, where the exchange of knowledge plays an important role.

Technological measures help to implement individual projects. The focus is on infrastructure which has to be built or improved, such as dams, reservoirs, fish ladders or water networks.

Policy approaches aim to support the national, international and basin-wide coordination of activities. Common transnational threshold values, limits, restrictions, expansions (e.g. for protection areas or nature reserves), etc. should be considered.

Table 11 provides examples of possible adaptation measures which are valid for almost all impact fields. More detailed information on these, and examples for other adaptation measures, can be obtained from the 'Danube Study', p. 39-45, tab. 2.

20 UNECE (2009): Guidance on water and adaptation to climate change. United Nations Publication, Geneva.
21 EEA (2010): The European Environment. State and Outlook 2010. Adapting to climate change – SOER 2010 thematic assessment. DOI: 10.2800/58998.

Examples for general adaptation measures *TABLE 11*

Preparation measures
Additional, intensified monitoring activities to follow and assess climate change and climate change impacts
Homogenous data production, digital mapping and a centralized database for data exchange and comparability among regions and countries
Identification of potential risk areas and hot spots
Implementation of forecasting and warning services (e.g. for extreme events such as floods and droughts)
Development of action plans or integration of specific issues into ongoing planning activities (e.g. to deal with water scarcity and flood situations)
Further research to close knowledge gaps, determine vulnerability or reduce uncertainty
Ecosystem-based measures
Taking environmental implications and the conservation of biodiversity into consideration in all other measures
Sustainable management of land use practices for improving resilience, and for enhancing the capacity to adapt to climate change impacts
Implementation of green infrastructure to connect bio-geographic regions and habitats
Protection, restoration and expansion of water conservation and retention areas
Rehabilitation of polluted water bodies
Behavioural and managerial measures
Support education, capacity building, awareness raising, information exchange and knowledge transfer
Establishment of and support for an integrated risk management
Support of a water saving behaviour
Propagation of best practice examples
Application of sustainable methods (e.g. good agricultural practices)
Technological measures
Adjustment of (existing) infrastructure, e.g. construction and modification of dams and reservoirs for hydropower generation, agriculture, drinking water supply, tourism, fish-farming, irrigation and navigation
Development and application of water-efficient technologies
Efficient waste- and sewage-water treatment and water recycling
Policy approaches
Support of an institutional framework to coordinate activities
Harmonization of international, basin-wide legal limits and threshold values
Implementation of restrictions (e.g. for development in flood risk areas)
Expansion of protection areas (e.g. for drinking water resources)
Adaptation of policies to changing conditions

For each impact field, future projections and possible adaptation measures classified into the five adaptation categories are described in detail in Chapter 5 of the 'Danube Study – Climate Change Adaptation'. It is recommended that the different tables from Chapter 5 be used as an inspiring list of possible adaptation measures for specific impact fields when discussing and agreeing on measures to be taken in the framework of planning processes (references in Table 12).

Link to tables of possible adaptation measures described in Chapter 5 of the 'Danube Study' *TABLE 12*

Impact field	Table No.	Page
Water availability	Tab. 3	p. 50- 51
Groundwater quality and quantity	Tab. 4	p. 54- 56
Ice/Snow/Permafrost	Tab. 5	p. 60- 61
Droughts, Low flow, Water scarcity	Tab. 6	p. 65- 70
Floods	Tab. 7	p. 74- 82
Water temperature	Tab. 8	p. 85- 86
Water quality	Tab. 9	p. 89- 93
Water supply/Water demand	Tab. 10	p. 97-102
Agriculture	Tab. 11	p. 105-112
Irrigation	Tab. 12	p. 114-116
Forestry	Tab. 13	p. 119-122
Land Use	Tab. 14	p. 124-125
Soils/Erosion	Tab. 15	p. 128-129
Biodiversity/Ecosystems	Tab. 16	p. 132-136
Limnology	Tab. 17	p.139
Coastal zones	Tab. 18	p. 141-142
Water-related energy production	Tab. 19	p. 145-149
Navigation	Tab. 20	p. 152-154
Health	Tab. 21	p. 157-159
Tourism	Tab. 22	p. 163-164

A changing climate affects all water-related sectors in different ways, both spatially and temporally. Therefore, disputes over the planning and utilisation of suitable adaptation measures may increase. Additionally, adaptation measures in one sector may have retroactive, positive or negative effects on one or more other sectors. To prevent possible conflicts and to foster common goals, cross-sectoral, interdisciplinary and integral approaches are necessary. Integral approaches also aim to enhance synergy effects which should be sought. An example of a synergy effect is an increase in water retention areas which can lead to a higher groundwater recharge, a reduction of flood peaks and positive effects for biodiversity.

SECTION III
Guiding principles, integration and next steps

This section provides guidance on the integration of climate change adaptation into ICPDR planning processes for the Danube River Basin. A set of guiding principles, *inter alia* specifically targeted towards making the WFD and EFD operational towards adaptation activities for water-related issues and sectors, is followed by an indication of the required approaches and steps for the next planning phase. Adaptation to climate change as a cross-cutting issue requires the involvement of a range of relevant ICPDR Expert and Task Groups, whereas the Strategy provides orientation on how to utilize this existing expertise for adaptation.

The next steps will require filling the Strategy with life by mainstreaming the suggested actions and integrating them into the planning activities leading to the 2nd DRBM Plan and the 1st DFRM Plan. Alongside the improvement of the knowledge base, the need to revise and update the Strategy should be assessed in 2018, in line with the six-year adaptive management cycles according to the WFD and EFD.

7 Guiding principles on adaptation and integration in ICPDR activities

7.1 Guiding principles on adaptation to climate change

This chapter gives an overview on guiding principles which provide support for the integration of adaptation to climate change into river basin management, including flood and drought risk management (see Table 13 taken from the CIS Guidance Document No. 24[22]). The principles should be generally applicable, and assist relevant experts, active in the framework of the ICPDR, during the next steps in the implementation process of the WFD and EFD in the Danube River Basin.

The guiding principles are particularly relevant for the planning process towards the 2nd DRBM Plan and the 1st DFRM Plan, to be elaborated by 2015. However, they are also applicable to the subsequent steps of WFD and EFD implementation, at both the national and international level.

The guiding principles are structured according to the following five main fields of actions, allowing orientation for relevant experts dealing with specific issues in the frame of river basin management:

I. Climate modelling, projections, scenarios, potential impacts and uncertainty
II. How to build adaptive capacity for management under climate change?
III. Water Framework Directive (WFD) and adaptation
IV. Flood risk management and adaptation
V. Drought management, water scarcity and adaptation

Further detailed descriptions, suggested actions and practical examples for each of the guiding principles, as summarised in Table 13, can be obtained from the CIS Guidance Document No. 24. The guiding principles on adaptation to climate change for flood risk management have already been addressed in the ICPDR concept paper in support of the implementation of the Directive 2007/60/EC in the Danube River Basin (IC-160 Coordination aspects of EFD implementation in the Danube River Basin).

Additional inspiring information is referenced in the Annex of the Strategy, providing an overview of case studies and good practice examples.

22 *European Communities (2009): Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 24. River Basin Management in a Changing Climate. Technical Report, Nr. 40.*

Guiding principles for adaptation to climate change from CIS Guidance Document No. 24[23] *TABLE 13*

Issue	Guiding principles
I. Climate modelling, projections, scenarios, potential impacts and uncertainty	
Models, projections and scenarios	1. Climate projections and scenarios should be used for improving river basin management planning.
	2. It is crucial to have a clear understanding of the assumptions made and the uncertainties related to these assumptions.
	3. The best climate change model or scenario for a certain region or river basin should be decided on a case-by-case basis, because there is no "one-size-fits-all" model or scenario for Europe.
Managing the water environment based on uncertainty of projections and scenarios	4. Despite uncertainty in models, ‚doing nothing' is not an option. For the next river basin management cycle, accept uncertainty where it is rational to do so and take first actions for adaptation to climate change.
	5. Take best available scientific information into account.
	6. Use a range of climate projections or scenarios in the analyses for river basin management planning in order to accept and work within the context of an uncertain future.
	7. Prefer adaptation options which are robust against a range of future changes or postpone commitment to a particular projection of the future by building flexibility into your system.
II. How to build adaptive capacity for management under climate change?	
Using ongoing research and adaptation activities to increase knowledge at river basin scale	1. Link river basin management adaptation activities to national and regional climate change adaptation strategies and activities.
	2. Check existing relevant science and research information on climate change modelling and impacts in the river basin.
	3. Make use of good-practice examples coming, e.g. from existing research and implementation experience regarding adaptation strategies and measures.
	4. Look beyond the borders of your river.
Data collection and building of partnerships	5. Evaluate coverage of data (e.g. meteorological, hydrological, water quality, soil moisture data, stake, damage cost data, etc).
	6. Use the WFD consultation process (Art. 14) to bring in sector-specific knowledge and data from key stakeholders.
	7. Ensure communication and coordination on climate change adaptation issues between different levels of management within an RBD.
	8. Work in cross-sectoral partnerships and across administrations. Ensure that climate change aspects are discussed between the relevant public administrations, in stakeholder meetings and discuss how relevant water-related sectors can contribute to adaptation.
	9. Make sure to receive information related to the influence of climate change on other sectors which are directly related to water management (e.g. agriculture-water demands, water needs for energy production, etc).
	10. Integrate cross-sectoral delivery of adaptation measures and coordinate activities with land use planning.
Broadening the audience and increasing its capacities - Awareness-raising, education and training	11. Include the issue of climate change impacts in the river basin in your RBD awareness-raising activities as part of the WFD public participation process.
	12. Establish staff training and capacity building programmes on climate change issues, e.g. to introduce staff to climate change modelling, scenarios and projections.
Looking beyond the borders	13. Develop joint or coordinated adaptation strategies in transboundary RBDs.

23 European Communities (2009): Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 24. River Basin Management in a Changing Climate. Technical Report, Nr. 40.

Issue	Guiding principles
III. Water Framework Directive (WFD) and adaptation	
Assessing pressures and impacts on water bodies	1. Assess, over a range of timescales, direct influences of climate change and indirect influences where pressures are created due to human activities adapting to climate change.
Monitoring and status assessment	2. Maintain both surface and groundwater surveillance monitoring sites for long time series. Set up an investigative monitoring programme for climate change and for monitoring climate change "hot spots", and try to combine them as much as possible with the results from the operational monitoring programme.
	3. Include reference sites in long term monitoring programmes to understand the extent and causes of natural variability and impact of climate change.
Objective setting	4. Avoid using climate change as a general justification for relaxing objectives, but follow the steps and conditions set out in the WFD.
Economic analysis of water use	5. Consider climate change when taking account of long term forecasts of supply and demand and favour options that are robust to the uncertainty in climate projections.
How to do a climate check of the Programme of Measures?	6. Take account of likely or possible future changes in climate when planning measures today, especially when these measures have a long lifetime and are cost-intensive, and assess whether these measures are still effective under the likely or possible future climate changes.
	7. Favour measures that are robust and flexible to the uncertainty and cater for the range of potential variation related to future climate conditions. Design measures on the basis of the pressures assessment carried out previously including climate projections.
	8. Choose sustainable adaptation measures, especially those with cross-sectoral benefits, and which have the least environmental impact, including GHG emissions.
What to do if other responses to climate change are impacting on the WFD objective of good status?	9. Avoid measures that are counterproductive for the water environment or that decrease the resilience of water ecosystems.
	10. Apply WFD Article 4.7 to adaptation measures that are modifying the physical characteristics of water bodies (e.g. reservoirs, water abstractions, dykes) and deteriorate water status.
	11. Take all practicable steps to mitigate adverse effects of counterproductive measures.

Issue	Guiding principles
IV. Flood risk management and adaptation	
Overall guiding principle on flood risk management and adaptation	1. Start adapting flood risk management to potential climate change as soon as possible, when information is robust enough, since full certainty will never be the case. Follow the guiding principles set out for the WFD.
Preliminary flood risk assessment	2. Understand and anticipate as far as possible climate change impact on flood patterns.
	3. Use best available information and data.
	4. Homogenize time series, and remove bias as far as possible.
	5. Understand and anticipate as far as possible increased exposure, vulnerability and flood risk due to climate change, for establishing areas of potential significant flood risk
Flood Hazard and Risk Maps	6. When identifying the different flood scenarios, incorporate information on climate change
	7. Present uncertainties surrounding climate change in maps transparently.
	8. Use the 6-year review of flood maps to incorporate climate change information
Flood Risk Management Objectives	9. Incorporate climate change in setting flood risk management objectives
	10. Ensure coordination at catchment level, also respecting the Directive's coordination requirements at RBD/unit of management level
Awareness raising, early warning, preparedness	11. Include climate change scenarios in ongoing initiatives and in the planning processes.
Measures	12. Perform a climate check of flood risk measures
	13. Favour options that are robust to the uncertainty in climate projections a. Focus on pollution risk in flood prone zones b. Focus on non-structural measures when possible c. Focus on "no-regret" and "win-win" measures d. Focus on a mix of measures
	14. Favour prevention through the catchment approach
	15. Take account of a long term perspective in defining flood risk measures (e.g. with respect to land use, structural measures efficiency, protection of buildings, critical infrastructure, etc). e. Include long-term climate change scenarios in land-use planning f. Develop robust cost-benefit methods which enable taking into account longer term costs and benefits in view of climate change.
	g. Use economic incentives to influence land use [Link insurance]
	16. Assess other climate change adaptation (and even mitigation) measures by their impact on flood risk: h. Hydropower and flow regulation i. Link with water scarcity
Links to WFD	17. Pay special attention to the requirements of WFD Article 4.7 when developing flood protection measures
	18. Determine on the basis of robust scientific evidence and on a case-by-case basis whether an extreme flood allows for the application of WFD Article 4.6.
	19. Pay special attention to the vulnerability of protected areas in view of changed flood patterns

Issue		Guiding principles
V. Drought management, water scarcity and adaptation		
Overall guiding principle on drought management, water scarcity and adaptation	1.	Use the Water Framework Directive as the basic methodological framework to achieve climate change adaptation in areas of water scarcity and to reduce the impacts of droughts.
River basin management plans as a tool for addressing water scarcity and droughts	2.	Make full use of the Water Framework Directive environmental objectives, e.g. the requirement to achieve good groundwater quantitative status helps to ensure a robust water system, which is more resilient to climate change impacts.
	3.	Determine, on the basis of robust scientific evidence and on a case-by-case basis, whether a prolonged drought allows for the application of WFD Article 4.6, and take into account climate change predictions in this case-by-case approach.
	4.	Pay special attention to the requirements of WFD Article 4.7 when developing measures to tackle water scarcity under a changing climate and which may cause deterioration of water status.
Monitoring and Detecting Climate Change Effects	5.	Diagnose the causes that have led to water scarcity in the past and/or may lead to it in the future.
	6.	Monitor water demand closely and create forecasts based on improved knowledge of demands and trends.
	7.	Collect as much high quality information as possible to anticipate changes in water supply reliability which may be imposed by climate change, in order to detect water scarcity early.
	8.	Distinguish climate change signals from natural variability and other human impacts with sufficiently long monitoring time series.
Adaptation measures related to water scarcity & droughts	9.	Take additional efforts to prevent water scarcity and be better prepared to tackle the impacts of droughts.
	10.	Incorporate climate change adaptation in water management by continuing to focus on sustainability (balance between water availability and demand).
	11.	Follow an integrated approach based on a combination of measures (compared to alternatives based on water supply or economic instruments only).
	12.	Build adaptive capacity through robust water resources systems.
	13.	Engage stakeholders to produce decisive measures to tackle water scarcity.
	14.	Assess other climate change adaptation and mitigation measures by their impact on water scarcity and drought risks.

7.2 Integration into ICPDR activities

7.2.1 General considerations

Climate change is a cross-cutting issue, causing impacts to different sectors on a transboundary scale. The quality of water and its availability are very much at the heart of the expected changes and therefore requiring coordinated action in an integrative way. Due to the transboundary character of water and its relevance for various issues and water-related sectors (e.g. its role for biodiversity and the ecosystem, energy, transport, agriculture, floods and droughts, etc.), integrated river basin management is key for ICPDR's approach to climate adaptation.

National experts covering a wide range of issues are cooperating in different ICPDR Expert and Task Groups on the coordinated implementation of the WFD and EFD. Taking advantage of this broad range of expertise is not only adequate but also crucial in order to address climate change accordingly, by integrating adaptation activities in the ongoing and future planning process of the ICPDR.

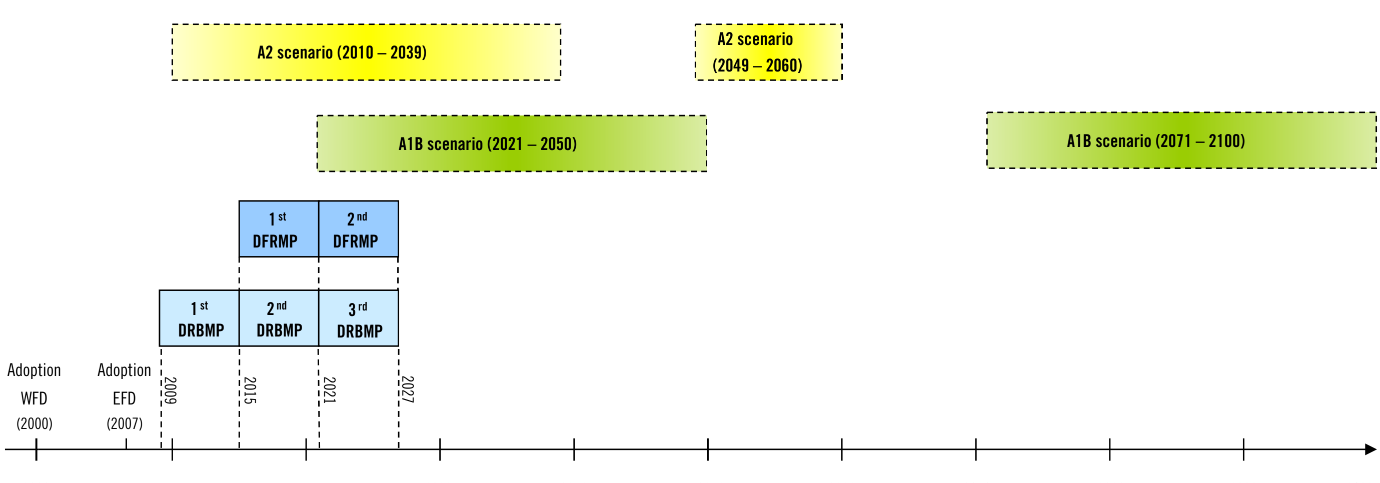
Building on this basic rationale, work on climate change adaptation will be anchored in existing ICPDR structures and planning instruments as well as the corresponding national institutions and structures, allowing to deal with the significant complexity of this issue.

All relevant ICPDR Expert Groups and Task Groups are therefore mandated to fully integrate adaptation to climate change in the planning process for the implementation of the WFD and EFD in the Danube River Basin, specifically for the elaboration of the next DRBM Plan and DFRM Plan.

7.2.2 Step-wise approach

The step-wise and cyclic approach of the river basin management planning process, for both the WFD and EFD, makes it well-suited to adaptively manage climate change impacts. On the basis of current knowledge, it is unlikely that the additional effects of a climate change signal can be adequately distinguished from other human pressures and natural variability within the next WFD and EFD planning cycle. It is more likely that indirect pressures arising from human response to climate change will have a greater impact (such as elevated water abstractions for irrigated agriculture, or new flood defence infrastructure)[24]. It is therefore essential to adjust adaptation actions in a step-wise manner, hand in hand with subsequent WFD and EFD planning cycles, building on increased experience and knowledge gained while taking into consideration climate change scenarios and expected water-related impacts (see Figure 11).

Overview of timeframe for WFD and EFD planning cycles in contrast to different climate change scenarios[25] *FIGURE 11*



24 See CIS Guidance Document No. 24

25 According to IPCC SRES scenarios and time periods described in Chapter 3 and illustrated in Figures 4 to 7

However, some of the implementation steps are considered to be more critical than others in our ability to prepare for climate change, especially in the short-term. Essential components for planning for climate change are judged to be:

- an ability to identify change as it happens through monitoring;
- ensuring that the likely scale of impacts of climate change on existing and projected future anthropogenic pressures and risks is understood, and
- developing and prioritising multiple-benefit catchment-based solutions which restore or maintain the natural characteristics of catchments, to build resilience to a range of possible climate futures. In this context, measures should be examined to ensure that they will not fail under future climatic conditions.

These components should be the focus when considering how to deal with climate change. As such, the pillars of the approach to adaptation in the framework of the 2nd DRBM Plan and the 1st DFRM Plan should be:

1. effective long-term monitoring (to enable climate change signals to be identified and reacted to in due course),
2. the assessment of the likely additional impact of climate change on existing and future anthropogenic pressures and risks, and
3. the incorporation of this information into the design of measures (particularly for proposed measures with a long-term design life).

Thus, it should be clearly demonstrated how climate change projections have been considered in the assessment of pressures, impacts and risks, in the monitoring programmes, and in the choice of measures.

7.2.3 How to integrate adaptation into ICPDR planning processes?

A range of different actions is required to adequately integrate adaptation into the ICPDR planning process for WFD and EFD implementation. These include overarching activities, such as the development of this Strategy or the future task of making use of improved climate modelling and building adaptive capacity for management under climate change (see fields of action I and II of Table 13). These also include other activities which have to be directly incorporated into the planning process, in particular: addressing monitoring and data exchange; the assessment of pressures, impacts and risks; and decision-making on measures (see fields of action III to V of Table 13). Therefore, it is suggested to address adaptation to climate change twofold.

Regarding the overarching activities, the main actions and steps to be taken will be included in the next DRBM Plan and DFRM Plan in separate chapters on climate change and adaptation, since these are activities of a more general nature with relevance to the overall adaptation process for the Danube River Basin.

Regarding the second issue, adaptation will be directly addressed in the relevant chapters of the WFD and EFD reports, in particular the 2nd DRBM Plan and the 1st DFRM Plan (e.g. how the monitoring system was adapted to enable tracking climate change signals, or how climate change has been taken into account in the required assessments and the decision on measures). The following main steps can be indicated, providing support for relevant experts in the accomplishment of this task:

1. Become familiar with the climate change scenarios and expected water-related impacts for the Danube River Basin (see Chapter 3 and Chapter 4 for an overview on the results of surveyed studies and more detailed information in the 'Danube Study – Climate Change Adaptation')
    a. Attain an overall overview of the expected changes
    b. Pay special attention to the different impact fields within your field of action and expertise
    c. Pay attention to the issue of uncertainty
2. Take into account the guiding principles on adaptation to climate change (Chapter 7.1), providing specific guidance on different steps to be taken in adaptation for different issues (i.e. fields of action III to V on WFD, EFD, water scarcity and drought management)
3. Incorporate this knowledge into your planning process and make use of additional supportive information (i.e. on vulnerability and possible adaptation measures: Chapter 5 and Chapter 6)
4. Make use of case studies and good practice examples (see Annex)

7.2.4 Integration between different levels of management

In the framework of the ICPDR, the transboundary aspects for the implementation of the WFD and EFD are coordinated at the basin-wide level (level A). Further detailed planning takes place at the sub-basin and/or national level (level B) as well as at the sub-unit level (catchments within national territories - level C). As with river basin and flood risk management, adaptation to climate change also requires communication and coordination between different levels of management within the Danube River Basin (see Chapter 2.2 on national and international adaptation activities).

In order to ensure coherence, it is therefore crucial that awareness on ongoing adaptation processes is created and an exchange takes place between experts working on adaptation at different levels, in particular between level A and level B. This will be guaranteed through the involvement of national experts in the international working groups of the ICPDR, respectively via existing coordination approaches between the basin-wide and the sub-basin level within the Danube River Basin (Sava, Tisza, Danube Delta, Prut).

7.2.5 Integration between different sectors, synergies and prevention of potential conflicts

The ICPDR is following an approach with the strong involvement of representatives from different sectors and interest groups in WFD and EFD planning processes (observer organisations, in particular). This is crucial to ensure the required exchange and input, which are expected to lead to better results in river basin and flood risk management. Exchange with, and input from, those groups will be maintained also with regard to climate change adaptation issues. In addition, the specific consultation processes, as required by the WFD (Art. 14) and EFD (Art. 9 & 10), should be used to bring in sector-specific knowledge and data from key stakeholders.

Apart from the involvement of observer organisations, further targeted exchange on climate change adaptation with specific experts and interest groups outside existing ICPDR structures will be undertaken (e.g. through participation in respective meetings or the organisation of specific workshops on adaptation).

Finally, synergies and potential conflicts need to be addressed at an early stage in the planning process and different stakeholders and interest groups need to be involved.

For example, the development of green infrastructure, such as the extension of natural areas and the re-connection of wetlands and floodplains, leads to the protection and maintenance of a natural ecosystem and can also help in the reduction of flood peaks. Further positive synergies which can be achieved by such adaptation measures can include the improved linkage between surface- and groundwater, leading to increased robustness with regard to potential periods of water scarcity and droughts.

On the other hand, structural adaptation measures for the improvement of navigation or for balancing water availability and water demand, in order to handle expected increasing water scarcity situations in the future, may lead to potential conflicts with regard to the achievement of biodiversity objectives.

8 Next steps

8.1 Implementation steps WFD and EFD

The ICPDR Strategy on Adaptation to Climate Change will be fully taken into account during the next steps of the implementation of the WFD and EFD in the Danube River Basin. Consideration of the next steps, as indicated in Table 14 on implementation, following the indicated deadlines, are crucial for the integration of adaptation to climate change.

Overview of next steps for WFD and EFD implementation *TABLE 14*

	Implementation step related to	
Deadline	EU Water Framework Directive	EU Floods Directive
22.12.2013	Update Danube Basin Analysis Report (agreed to be accomplished by first half of 2014)	Danube flood hazard and flood risk maps
22.12.2014	Draft 2nd Danube River Basin Management Plan available for public consultation	Draft 1st Danube Flood Risk Management Plan available for public consultation
22.12.2015	Final 2nd Danube River Basin Management Plan	Final 1st Danube Flood Risk Management Plan

8.2 Closing of knowledge gaps and identification of further research requirements

The 'Danube Study – Adaptation to Climate Change' identified besides commonalities in the impact studies also knowledge gaps and requirements for further research. A prerequisite for achieving progress in this regard is having professionals who are able to apply the required activities (institutional adaptation), including the establishment and maintenance of databases, measurement networks, simulation models, analysis software, laboratories, knowledge management systems or adjusted processes in the concerned institutions etc.

To improve the understanding of ongoing changes and their impacts, better observational data and data access are necessary. Quality assurance and the homogenization of data sets help to improve model projections and are a prerequisite for adaptive management required under conditions of climate change within transboundary regions or catchments. In particular, changes in water availability, as well as changes in water demand, in the Danube basin are of high interest on a monthly or higher temporal resolution scale.

There is a need to compare climate impacts across sectors and to systematically assess climate risks, preferably based on a commonly agreed methodology and database. A basin-wide assessment could guide the selection of regional hot spots for detailed impact studies. An interdisciplinary research team can acquire a multi-sector impact aggregation and a damage and risk assessment for short-term, medium-term or long-term applications.

The synergies and conflicts between climate change and land use planning need to be clarified. Feedbacks between land use and climate change (including vegetation change and anthropogenic activity such as irrigation and reservoir construction) should be analysed more extensively (e.g. by coupled climate and land use modelling). Furthermore, an evaluation of the water-related consequences of different climate policies and development pathways is also of importance for a common adaptation strategy. Alongside climate change impacts, socio-economic and demographic aspects are also crucial for future adaptation measures.

A basin-wide approach which covers all relevant hydrological parameters is valuable to determine the impacts and consequences of climate change in the Danube River Basin. Particularly, the Middle and Lower Danube River Basin might benefit from this approach due to the relatively sparse information existing on climate change impacts in these regions. Given the expected increasing water scarcity and drought situations in future summer periods in the southeastern regions, a basin-wide approach can give advice for the solutions for transboundary environmental crises and suitable adaptation measures. The assessment of water needs for the main utilities under several future circumstances (e.g. under severe drought and water shortage conditions) can be projected. Upstream-downstream dependencies, also taking into consideration socio-economic and demographic changes, should be clearly presented.

Furthermore, model projections for the whole Danube basin with better land-surface properties and interactions as a large-scale climate model can provide suitable information on the catchment scale – the most important scale for water management.

8.3 Revision and update

In line with the step-wise and cyclic approach for the implementation of the WFD and EFD, it is proposed to check the need to update and revise the ICPDR Strategy on Adaptation to Climate Change. This should take place within an appropriate timeframe, allowing to:

- Take into account updated information regarding the knowledge base on climate change and adaptation, in particular on climate change scenarios and water-related impacts in the Danube River Basin; and
- Take the updated and revised Strategy into account for the planning process of the 3rd DRBM Plan and the 2nd DFRM Plan, due by 2021.

Based on these considerations, it is proposed to check the need for an update of the ICPDR Strategy on Adaptation to Climate Change in 2018, linking it with the six-year planning cycles according to the WFD and EFD.

Annex – List of Case Studies and Good Practice Examples

The list below is an indicative list of case studies and good practice examples. For further information, please consult the Appendix of the 'Danube Study – Climate Change Adaptation'[26], available on the ICPDR website following the link: http://www.icpdr.org/main/activities-projects/climate-adaptation

Vulnerability and adaptation

ADWICE	Adapting Drinking Water resources to the Impacts of Climate change in Europe (ongoing). http://adwice.biois.com/
ATEAM	Advanced Terrestrial Ecosystem Analysis and Modelling. The aim is to assess the vulnerability of human sectors relying on ecosystem services with respect to global change. www.pik-potsdam.de/ateam
ClimWatAdapt	Climate Adaptation – modelling water scenarios and sectoral impacts. The project results represent a series of tools which shall help to improve the quality of adaptation measures and the knowledge base, and to facilitate the exchange of adaptation best practices between countries and regions. www.climwatadapt.eu
EEA-EIONET	European Topic Centre on Inland, Coastal and Marine waters. Report on good practice measures for climate change adaptation in river basin management plans, 2009. http://icm.eionet.europa.eu/ETC_Reports/
MOTIVE	Models for Adaptive Forest Management. The project investigates adaptive management strategies that address climate and land use change. http://motive-project.net
UNECE	Transboundary pilot projects on climate change adaptation: http://www1.unece.org/ehlm/platform/display/ClimateChange/Welcome - UNECE Guidance on Water and Adaptation to Climate Change (2009) - UNECE Guidance on Water Supply and Sanitation in Extreme Weather Events (2011) - Transboundary Flood Risk Management – Experience from the UNECE region (2009)

Information systems

BISE	Biodiversity Information System for Europe. Facts and figures on biodiversity and ecosystem services, developed to strengthen the knowledge base and support decision-making on biodiversity. http://biodiversity.europa.eu
CLIMATE-ADAPT	The European Climate Adaptation Platform aims to support Europe in adapting to climate change. www.climate-adapt.eea.europa.eu
ESPON	European Observation Network for Territorial Development and Cohesion. Supports policy development by providing comparable information, evidence, analyses and scenarios on territorial dynamics, and revealing territorial capital and potentials for development of regions and larger territories. www.espon.eu
WISE	Water Information System for Europe. Water-related information ranging from inland waters to marine. http://water.europa.eu/

26 *Prasch, M., Koch, F., Weidinger, R., Mauser, W. (2012): Danube Study - Climate Change Adaptation. Ludwig-Maximilians-University Munich, Department of Geography. Final Report (available on icpdr-website).*

Regional studies

AdaptAlp	Adaptation to climate change in the Alpine Space. http://www.adaptalp.org/
ADAM	Adaptation and mitigation strategies. The Tisza River Basin: Adaptation to climate change in floodplain management. http://www.tyndall.ac.uk/adamproject/tisza-river-basin
Anpassungsstrategien an den Klimawandel für Österreichs Wasserwirtschaft, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wien, 2010, http://www.lebensministerium.at/publikationen/wasser/wasserwirtschaft_wasserpolitik/anpassungsstrategien_an_den_klimawandel_fuer_oesterreichs_wasserwirtschaft.html	
Climate proofing the Danube Delta through integrated land and water management (ongoing)	
KomPass	Competence Centre for Climate Change and Adaptation. Germany. www.anpassung.net
KLIMZUG	Climate change in regions. Germany. www.klimzug.de
klimazwei	Minimize risks, use chances. Germany. Projects on climate protection, climate change and adaptation. Development of practice-oriented strategies. www.klimazwei.de
KlimalWandellAnpassung – Adaptation to Climate Change. Austria. www.klimawandelanpassung.at	

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the Parliament of the Federal Republic of Germany

This document has been produced with the financial assistance of the European Union. The views expressed herein can in no way be taken to reflect the official opinion of the European Union

Contact
ICPDR Secretariat
Vienna International Centre / D0412
P.O. Box 500 / 1400 Vienna / Austria
T: +43 (1) 26060-5738 / F: +43 (1) 26060-5895
icpdr@unvienna.org / www.icpdr.org

Imprint
Published by:
ICPDR – International Commission for the Protection of the Danube River

Prepared by:
ICPDR River Basin Management Expert Group
with support of Ludwig-Maximilians-Universitaet Munich
(Wolfram Mauser, Ruth Weidinger, Monika Prasch, Franziska Koch)

Technical coordination: Raimund Mair

Publishing coordination: Benedikt Mandl
Proof-reading: Paul Csagoly
Photos: Janez Polajnar, MOP ARSO Ljubljana, Hrvatske Vode Zagreb, SVP Banska Stiavnica, IzVRS Ljubljana (Brane Klinic), Günter Mair

Layout: Büro X, www.buerox.at

//// Deutschland //// Österreich //// Česká republika //// Slovensko //// Magyarország //// Slovenija //// Hrvatska //// Bosna i Hercegovina //// Србија //// Crna Gora //// România //// България //// Moldova //// Україна //