



# River basin management in a changing climate

Common Implementation Strategy for the  
Water Framework Directive and the Floods Directive

Guidance document No. 24

Version 13 - 12 June 2024  
Document endorsed by EU Water Directors at their meeting in Ghent on 12 June 2024



Manuscript completed in June 2024

13<sup>th</sup> edition

#### **Disclaimer**

This technical document has been developed through a collaborative framework (the Common Implementation Strategy) involving the Member States, European Free Trade Association countries, and other stakeholders, including the European Commission. The document reflects the informal consensus position on best practices acknowledged by the EU Water Directors. However, the document does not necessarily represent the position of any of the partners.

To the extent that the European Commission's services provided input to this technical document, such input does not necessarily reflect the views of the European Commission.

This technical document is intended to facilitate the implementation of Directive 2000/60/EC and Directive 2007/60/EC and is not legally binding. Any authoritative reading of the law should only be derived from Directive 2000/60/EC and Directive 2007/60/EC itself and other applicable legal texts or principles. Only the Court of Justice of the European Union is competent to authoritatively interpret Union legislation.

Luxembourg: Publications Office of the European Union, 2024

© European Union, 2024



The reuse policy of European Commission documents is implemented by Commission Decision 2011/833/EU of 12 December 2011 on the reuse of Commission documents (OJ L 330, 14.12.2011, p. 39). Unless otherwise noted, the reuse of this document is authorised under a Creative Commons Attribution 4.0 International (CC BY 4.0) licence (<https://creativecommons.org/licenses/by/4.0/>). This means that reuse is allowed provided appropriate credit is given and any changes are indicated.

For any use or reproduction of photos or other material that is not under the copyright of the European Union, permission must be sought directly from the copyright holders.

PDF ISBN 978-92-68-19443-0 doi:10.2779/126657 KH-09-24-604-EN-N

#### **DIRECTORATE-GENERAL FOR ENVIRONMENT**

Directorate C — Zero Pollution  
Unit C.1 — Sustainable Freshwater Management

*European Commission*  
*B-1049 Brussels*

# **River basin management in a changing climate**

Common Implementation Strategy for the  
Water Framework Directive and the Floods Directive

Guidance document No. 24

## Table of contents

Table of contents.....	4
LIST OF ABBREVIATIONS .....	7
EXECUTIVE SUMMARY .....	9
1 INTRODUCTION .....	21
2 CLIMATE MODELLING, PROJECTIONS AND SCENARIOS .....	24
2.1 Observed climate change at the global level.....	24
2.2 Climate Change observations and projections for the EU and their impacts.....	25
2.3 Impact on water body status.....	28
2.4 Socio-economic impacts on water-dependent sectors and society.....	29
3 WATER AND CLIMATE CHANGE – EU POLICY FRAMEWORK.....	31
4 TOWARDS RESILIENCE FOR WATER MANAGEMENT UNDER CLIMATE CHANGE ..	34
4.1 STEP 1: Preparing the ground for adaptation by Strengthening Adaptive Capacity .....	35
4.2 STEP 2: Assessing vulnerability to climate change in water management planning .....	36
4.3 STEP 3: Identifying adaptation options by considering different adaptation pathways .....	38
4.4 STEP 4 Assessing adaptation options .....	42
4.5 STEP 5 Implementation .....	43
4.6 STEP 6: Monitoring & Evaluation.....	45
5 WATER FRAMEWORK DIRECTIVE AND ADAPTATION .....	46
5.1 Pressure and impact assessment.....	47
5.1.1 Surface Water.....	47
5.1.2 Groundwater .....	49
5.2 Status Assessment .....	50
5.2.1 Surface water body typology, reference conditions and classification .....	50
5.2.2 Groundwater bodies .....	53
5.2.3 Protected Areas .....	54
5.3 Monitoring .....	55
5.3.1 Monitoring of surface water.....	55
5.3.2 Monitoring of groundwater status.....	56
5.4 Exemptions .....	58
5.5 Economic analysis .....	61
5.6 Measures for adaptation related to the WFD .....	62
5.6.1 Types of Measures and Principles for Selection .....	62

5.6.2	Financing of adaptation measures.....	64
5.6.3	Cost recovery efforts.....	65
6	FLOOD RISK MANAGEMENT AND CLIMATE ADAPTATION .....	66
6.1	Preliminary flood risk assessment (PFRA).....	68
6.2	Flood hazard and risk maps (FHRM) .....	69
6.3	Flood risk management plans .....	70
6.3.1	Flood risk management objectives.....	70
6.3.2	Measures for adaptation related to the FD .....	70
6.3.3	Adopting an integrated approach .....	71
6.3.4	Awareness raising, early warning and preparedness.....	72
6.3.5	Improving the process of integrating climate change science into flood risk management practice	72
7	DROUGHT MANAGEMENT AND CLIMATE ADAPTATION .....	72
7.1	River basin management plans and drought management plans as tools for addressing water scarcity and droughts .....	73
7.2	Monitoring and detecting climate change effects on droughts and water scarcity .....	75
7.3	Adaptation measures related to water scarcity & droughts.....	76
7.4	Priority Water Allocation under water scarcity conditions.....	77
8	NATURE-BASED SOLUTIONS FOR RESILIENCE & CLIMATE ADAPTATION.....	81
8.1	Costs and benefits .....	83
8.2	Implementation challenges .....	84
8.3	NBS supporting the implementation of WFD and FD.....	85
8.4	NBS and droughts .....	86
9	CROSS-BORDER/TRANSBOUNDARY ASPECTS OF CLIMATE ADAPTATION .....	87
10	HOW TO DO A CLIMATE CHECK OF MEASURES (ADAPTATION AND MITIGATION)?	91
10.1	Step 1: Screening phase for KTMs and Sub-KTMs at PoM level .....	92
10.1.1	Application: Assessment area 1 ‘Climate Robustness’ .....	92
10.1.2	Application: Assessment area 2 ‘Effects on climate change’ .....	97
10.2	Step 2 Detailed proofing of infrastructure projects.....	98
10.2.1	Climate Neutrality – Mitigation of climate change.....	99
10.2.2	Climate Resilience – Adapting to climate change .....	100
11	ANNEX I: ADAPTATION ACTIONS/MEASURES – SOURCES OF INFORMATION .....	103
11.1	General measures .....	103
11.2	Urban measures.....	104

11.3	Rural measures.....	105
12	ANNEX II EXAMPLES OF THE IMPACT OF CLIMATE CHANGE ON THE QUALITY ELEMENTS.....	105
13	ANNEX III: ROLE OF THE SEA AND EIA PROCESS IN CLIMATE CHANGE ADAPTATION	107
14	GLOSSARY .....	108
15	References.....	112

## LIST OF ABBREVIATIONS

BWD – Bathing Water Directive

CIS – Common Implementation Strategy

CEMS – Copernicus Emergency Management Service

DMP – Drought Management Plans

DWD – Drinking Water Directive

EEA – European Environment Agency

EIA – Environmental Impact Assessment

EQR – Ecological Quality Ratio

FD – Floods Directive

FHRM – Flood Hazard and Risk Maps

FRMP – Flood Risk Management Plans

GEP/GES – Good Ecological Potential/Good Ecological Status

GHG – Greenhouse Gases

GWD – Ground Water Directive

IPCC – Intergovernmental Panel on Climate Change

JRC – Joint Research Centre

KTM – Key Type of Measure

MS – Member State of the European Union

NBS – Nature-based Solutions

PFRA – Preliminary Flood Risk Assessment

PoM – Programmes of Measures

RAST – Regional Adaptation Support Tool

RBD – River Basin District

RBM – River Basin Management

RBMP – River Basin Management Plans

WFD – Water Framework Directive



## EXECUTIVE SUMMARY

### INTRODUCTION

1. Europe's fresh, transitional, coastal and marine waters have been affected by centuries of anthropogenic usage as well as by the unintended consequences of changes in land use, water abstraction and pollution. These anthropogenic pressures are exacerbated by the direct and indirect effects of climate variability and change, increasing the challenges associated with achieving and maintaining good status.
2. The purpose of this updated guidance document is to i) update information on climate change impacts on the water cycle and ii) provide tools to help water managers align river basin management (RBM) planning under the **Water Framework Directive** (WFD), the **Floods Directive** (FD) and to manage droughts through climate adaptation planning by describing guiding principles for water management and adaptation. The principles are intentionally broad to be applicable across all Member States (MS) regardless of regional variations in potential impacts. Where feasible, entry points have been identified within existing processes and frameworks. Examples are provided to show how the principles might be applied in practice.
3. Although climate change is not explicitly included in the text of the WFD, the stepwise and cyclical approach of the RBM planning process is well suited to adaptively manage climate change impacts, building on climate adaptation plans in the member States.
4. More than two decades of experience with the RBMP process demonstrate that **integrated water management** is the best approach to balance available water resources and demands, thus avoiding long-term water scarcity while also managing flood risks, which is specifically addressed by the requirements of the Floods Directive.
5. In 2019, the European Union's **Green Deal** was launched to transform the Union into a modern, resource-efficient, and competitive economy, ensuring no more net emissions of greenhouse gases by 2050, and making Europe the first climate neutral continent. The ambition is to decouple economic growth from resource use while leaving no person and no place behind. As part of the Green Deal, the European Commission adopted a set of legislative proposals<sup>1</sup> to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.
6. In 2021, the European Commission adopted its new **EU strategy on adaptation to climate change** as part of the European Green Deal, aiming to intensify efforts to

---

<sup>1</sup> The legislative proposals of direct relevance to integrated water management are in particular those under the "[Biodiversity Strategy 2030](#)", the "[Zero Pollution Action Plan](#)" and the "[From Farm to Fork](#)" strategies. See also below in section 3.

protect nature, communities, and livelihoods from the unavoidable impacts of climate change. This strategy coincided with the implementation of the European Climate Law which implements the Paris Agreement's objectives.

7. The **European Climate Law** (2021) obliges EU Member States to adopt national and regional climate adaptation strategies which must consider the vulnerabilities of different sectors such as in particular those of the water/soil/food nexus and promote nature-based solutions (NBS). Regular updates to these strategies every five years and the inclusion of updated information in climate adaptation reports are required. The Commission assesses the compliance of national measures with the adaptation plans and makes recommendations for improvement.
8. In March 2024 the EEA published the first ever **European Climate Risk Assessment**, indicating that Europe's climate risks have already reached critical levels and could become catastrophic without urgent and decisive action. Shortly after the publication of the assessment, the European Commission adopted the **Communication on managing climate risks in Europe**.

#### CLIMATE CHANGE

9. Human-driven increases in atmospheric greenhouse gases (GHG) cause rapid warming across various Earth systems.
10. Without significant emission reductions, global warming of 1.5°C to 2°C will be exceeded this century, already leading to irreversible changes in oceans, ice sheets, and sea levels, exacerbating extreme weather events and water-related risks globally.
11. Compared to pre-industrial levels, the average temperatures have risen by 1.94 to 2.01°C in Europe from 2010-2020, with the warmest years occurring in the past decade. In fact, 2023 was the warmest year on record over more than 100,000 years globally. Europe is the fastest-warming continent; since the 1980s, warming on the continent was about twice the global rate. Extreme heat is becoming increasingly common, exposing a large share of the population to heat stress, particularly in Southern and Western Europe. More intense and frequent weather extremes, including droughts but also floods, are projected, with southern regions particularly vulnerable to extreme heat, water scarcity, and forest fires.
12. Changes in precipitation patterns will reshape waterbodies and may degrade biodiversity through scouring or desiccation. More frequent and more extreme floods can overwhelm urban wastewater systems, increasing nutrient loads and storm overflows. Prolonged droughts reduce the dilution of pollutants in rivers, exacerbating pollution and degrading the soil. Sea level rise threatens coastal regions, leading to salinisation of freshwater sources and submerging tidal marshes, impacting biodiversity and water quality.

13. Increasing water temperatures disrupt aquatic ecosystems, altering nutrient cycles and causing fish kills. Warmer temperatures affect stratification in lakes and coastal waters, reducing oxygen levels and disrupting species phenology. Geochemical processes are affected by temperature, with soil moisture deficit leading to increased nitrogen mineralisation.
14. Climate-related weather extremes in Europe, including floods and storms, have led to approximately €650 billion in losses from 1980 to 2022. With further global warming, these impacts will continue to rise, making bold adaptation action in sectors like agriculture, industry, energy, and waterborne transport a necessity.

## WATER AND CLIMATE CHANGE – EU POLICY FRAMEWORK

15. Several existing European Union (EU) policies address water management issues. The most important are the WFD, the FD, the Drinking Water Directive (DWD), Groundwater Directive (GWD) and the Bathing Water Directive (BWD). Collectively, they provide legal instruments for protecting and restoring the water environment.
16. The European Green Deal initiated legislative proposals of direct relevance to integrated water management. These proposals are in particular those under the "[Biodiversity Strategy 2030](#)" to restore the broken water cycle and restoring the sponge function of soils and forests, under the "[Zero Pollution Action Plan](#)" to reduce pollutions of water and air, and under the "[From Farm to Fork](#)" strategy to make conventional agriculture more sustainable. At the time of revising this CIS 24, several of these legislative proceedings had already been closed and achieved important improvements<sup>2</sup>, while others will continue during the next mandate of the Commission 2025-2029.<sup>3</sup>

## PLANNING FOR ADAPTATION TO CLIMATE CHANGE

17. Resilience is crucial for social-ecological systems and involves withstanding shocks, recovering from, and adapting to present and future stressors. Climate adaptation is key to water system resilience, addressing stressors and fostering stability. Both the

---

<sup>2</sup> The [revised Drinking Water Directive](#) is applicable since 12.1.2024 and will contribute to increase water conveyance efficiency by reducing leaks, and improving drinking water quality by prohibiting certain substances. The [new Water Reuse Regulation](#) is applicable since 26.6.2023 and allows Member States to reuse waste water for irrigation in agriculture subject to strict conditions and strict controls.

<sup>3</sup> A proposed [Nature Restoration Law](#) aims a.o. at repairing the broken water cycle and restoring the sponge function of soils and better lateral and longitudinal continuity of rivers. The proposed revision of the [Industrial Emissions Directive](#) would also contribute to more water efficiency in the manufacturing sector and extend the directive's scope to large pig and poultry farms. The proposed [revision of pollutants](#) in groundwater and surface waters would update Europe's black list in line with latest scientific findings. A proposed [soil monitoring law](#) aims at protecting and restoring soils to ensure that they are used sustainably.

[guidelines](#) on Member States' Adaptation Strategies and Plans as well as the [Regional Adaptation Support Tool](#) (RAST), with a six-step approach, supports developing climate adaptation strategies, including water protection and infrastructure enhancements.

18. Importantly, climate change impacts on water quality and quantity are intertwined with other anthropogenic pressures, like pollution and habitat destruction. Integrating a RAST – type of analysis prior to or within the RBMP processes can help address these challenges comprehensively, ensuring coordinated responses to both climate and human-induced stressors on water systems. These six steps of the RAST consists of:
  19. STEP 1: Preparing the ground for adaptation by strengthening adaptive capacity:
    - To strengthen the adaptive capacity in water management it is essential to understand the climate risks, collect data, and develop tailored strategies.
    - Key actions include establishing financial mechanisms, identifying stakeholders, and fostering cross-sectoral partnerships.
    - Integration of climate change impacts into awareness-raising activities and staff training programmes is essential for effective adaptation.
  20. STEP 2: Assessing risks and vulnerability to climate change as part of water management planning:
    - To analyse current and future climate risks and potential hazards a vulnerability assessment should be implemented, evaluating impacts across sectors, and considering uncertainties.
    - This assessment must encompass risks to water resources, ecosystems, community services, and infrastructure, considering various climatic scenarios<sup>4</sup> and uncertainties.
    - Collaboration and participation of authorities and stakeholders is essential to ensure the assessment covers all pertinent hazards and evaluates their impacts across sectors.
  21. STEP 3: Identifying adaptation options by considering different adaptation pathways:
    - There are often many possible ways to respond to climate change. Often a combination of different actions, some of which are taken now and some later, present the best way forward. To identify competing options, and decide on the
-

most effective ones, and their sequencing, it is recommended to develop WFD programmes of measures along climate adaptation pathways.

- Authorities identify sets of potential adaptation pathways addressing climate change consequences and other pressures. The options include structural and non-structural measures like water reuse and land use change.
- Public consultations should support adaptation measure identification under the WFD, including specific measures to address droughts and water scarcity (e.g., strategies, DMPs), and FD, aligning with national/regional climate adaptation strategies for policy coherence.

22. STEP 4 Assessing and selecting adaptation options:

- The assessment and ranking of water management/adaptation options are based on effectiveness, feasibility, costs, and climate-proofing, ensuring alignment with WFD and FD objectives.
- Climate-proofing enhances resilience to climate change impacts while maintaining water management objectives, aiming to avoid maladaptation and unintended consequences. Authorities should strive to avoid maladaptation which occurs when adaptation actions also have negative side-effects or outcomes for the environment, compromising GES/GEP and potentially even increasing CO<sub>2</sub> emissions ('Do No Significant Harm' - DNSH - principle).
- Just Resilience focuses on reducing unequal climate risks burdens and ensuring equitable distribution of adaptation benefits, considering gender-specific vulnerabilities and social welfare in the cost-benefit analysis. Meaningful engagement is needed with vulnerable groups to address social vulnerabilities for drought and flood risk management.

23. STEP 5 Implementing adaptation:

- Implementation involves enacting preferred climate adaptation options using a range of instruments such as legal, economic, informational, partnership, and hybrid strategic/planning instruments.
- Mainstreaming water adaptation planning across sectoral policy-making levels is crucial for coherence and synergy, minimising conflicts, and reducing the need for trade-offs.
- Water resilience from the outset of larger infrastructure projects can prevent costly adaptation measures later and contribute to climate mitigation and disaster risk reduction.

24. STEP 6: Monitoring & Evaluation adaptation

- Continuous monitoring and evaluation of climate adaptation and water management planning are vital to track progress, assess outcomes and adjust the plan. It is all the more important for Member States to conduct monitoring of water resources as outlined in the WFD and the FD.

## WATER FRAMEWORK DIRECTIVE AND ADAPTATION

25. Building on this six-step approach to climate adaptation planning, climatologists and water managers can identify climate change induced challenges for the resilience of water ecosystems. Critical RBM steps for climate readiness include robust long-term monitoring, understanding climate impacts, and securing funding for measures to achieve the WFD, FD, GWD etc. objectives.
26. Water managers should be able to distinguish climate change pressures from anthropogenic pressures to know which pressures they can influence, and which ones are a direct consequence of climate change. In respect of anthropogenic pressures, Article 5 of the WFD requires MS to regularly review the impact of human activity on the status of surface waters and groundwaters.
  - The evaluation of these pressures on surface water bodies should consider climate impacts and sectoral developments and the integration of future projections into models for comprehensive assessments. The development of adaptation strategies in the RBMPs should be aligned with national climate adaptation plans, including improved measures and NBS to tackle the adverse impact induced by climate change.
  - The assessment of groundwater vulnerability should use models and meteorological criteria, accounting for short- and long-term climate risks, like prolonged droughts. Standardised approaches for attributing changes to climate factors should be developed, aiding robust adaptation planning and WFD implementation.
27. Some types of water bodies may permanently change because of climate change despite additional measures being implemented. If so, these water bodies should be assigned to an appropriate type within the existing typology and the corresponding reference conditions applied to them. If there is no possibility for re-assignment to an existing type, a new type could be created or an existing one updated with its specific reference conditions and class boundaries.
28. The status assessments should be based on transparent criteria and should be supported by robust and long-term monitoring data, to detect water body responses to climate change and to accurately assess the ecological and chemical status considering climate change impacts. Climate change may affect water body typology, for example through altered morphology, hydrology, nutrient or salinity dynamics. Water bodies can

therefore migrate from one type to another because of gradual climate change or a sequence of extreme events.

29. A groundwater status assessment under the WFD considers thresholds, trends, and indicators affected by climate change pressures, with methods outlined in the CIS Guidance Document No 18, emphasising the need to balance natural recharge, avoid alterations detrimental to ecosystems, and address the impacts of sea level rise. Assessment methods vary and can include spring flow measurements, volume calculations, and water balance assessments. In some countries, this assessment will include the consideration of regard ecological needs and the impact of sea level rise, highlighting the importance of ecologists' input in specifying ecological requirements.
30. WFD Article 7 (drinking water abstraction areas) should be considered when addressing climate-related challenges as for current extraction the drinking water standards need to be met and water bodies for future use be secured.
31. The efforts to protect Natura 2000 areas from the impacts of climate change require often improved water management. A combined approach is needed to ensure biodiversity conservation.
32. Another important aspect of climate change adaptation in water management is the appropriate monitoring of trends, as climate change impacts may be noticeable only in longer time series. Long-term surface water and groundwater monitoring can indicate climate change signals and help assess impacts on aquatic ecosystems, however this necessitates careful planning and consistent methodologies. Enhanced monitoring efforts in vulnerable groundwater environments and during extreme events better capture gradual changes in ground- and surface water interactions as well as seasonal variations, providing a robust scientific basis for proactive adaptation strategies.
33. Article 4.4 and 4.5: Exemptions under the WFD should be used sparingly (see also CIS Guidance No. 20) and climate change should only be considered as a valid justification for permanently decreasing objectives where all legal conditions are met based on robust evidence, avoiding reliance solely on modelled assumptions. Long-term analysis and complete evidence-based analysis should guide decisions on accepting less stringent environmental objectives in line with WFD principles, also considering uncertainties of climate projections.
34. Article 4.6: The application of temporary exemptions due to prolonged droughts and extreme floods must equally be based on robust scientific evidence, while distinguishing in particular between droughts and water scarcity. Where climate change exacerbates anthropogenic pressures, anthropogenic pressures should be reduced as a matter of priority.

35. Article 4.7: Adaptation measures for climate change impacts may require heavy modifications to water bodies such as the construction of flood dams. Article 4 (7) WFD allows for such modifications under strict conditions. Repercussions on the ecological status of surface water bodies should always be limited to the minimum necessary for achieving a legitimate objective. Once heavy modifications become inevitable, a good ecological potential should be defined and achieved. Importantly, infrastructure projects necessitating exemptions under Art. 4(7) should also undergo a climate-proofing to avoid maladaptation.
36. Economic analysis in WFD implementation potentially becomes more crucial with changing climatic conditions, requiring an integration of potential climate change impacts and constraints. For instance, assessing measures under multiple climate scenarios can help identify cost-effective options to meet the WFD objectives.
37. Financing adaptation measures for WFD objectives and flood risk mitigation may require substantial investments. Despite financial constraints, diverse funding sources are available, necessitating good knowledge of funding opportunities and their applicability. Cost recovery efforts, guided by WFD Article 9, should account for financial, environmental, and resource costs, aligning with the Polluter-Pays-Principle and ensuring adequate incentives for efficient water use.
38. The WFD necessitates timely and climate-robust measures in RBMPs to achieve environmental objectives, including grey, green, and soft options. Incorporating climate change predictions into the selection of measures in RBMPs should align with the precautionary principle and preventive action. The selection of measures should comply with the precautionary principle and the principles that preventive action should be taken regarding environmental protection (Article 174 of the European Treaty). Changing climatic conditions may require additional measures going beyond basic measures to achieve WFD objectives, particularly addressing hydromorphological or physico-chemical changes, or an increased risk of invasive species due to rising temperatures.

## FLOOD RISK MANAGEMENT AND CLIMATE ADAPTATION

39. In the **Preliminary Flood Risk Assessment** (PFRA) the consideration of climate models enhanced the understanding of flood hazard changes due to climate change. However, challenges exist in integrating raw model outputs into flood frequency estimations, necessitating collaboration with national meteorological services for consistent climate projections across various assessment levels. It is prudent to consider future land use changes alongside climate projections. These changes can significantly impact flood flows, necessitating an evaluation of their individual and combined effects on the flood risk. Despite challenges in distinguishing between land use and climate change impacts, their consideration is vital for a comprehensive flood risk assessment.

40. Illustrating changes in flood extent under different climate scenarios in **Flood Hazard and Risk Maps** (FHRM), although not mandatory, would enhance awareness and understanding. Continued development of analytical and cartographic methods is crucial to visualise probabilities and uncertainties, improving flood-mapping accuracy and aiding in climate change adaptation planning.
41. **Flood Risk Management Plans** (FRMP) mandate objectives focusing on mitigating flood consequences and reducing likelihood. Synergies with the WFD and other EU policies ensure holistic risk reduction strategies, considering climate change impacts and integrating environmental objectives. Effective measures should prioritise long-term prevention, robustness to climate uncertainty, community resilience, and stakeholder consultation, following guidance from global institutions like the World Meteorological Organisation (WMO) to incorporate climate projections into planning.
42. Adopting integrated flood management approaches strengthens societal resilience by combining risk management principles with NBS, stakeholder participation, and harmonised water and land management strategies, aligned with the principles of Integrated Flood Management. Public awareness campaigns, digital flood viewers, and educational initiatives enhance flood risk understanding and promote adaptation measures. Improved civil protection measures and multi-hazard disaster preparedness are vital responses to increased climate-induced hazards, ensuring communities are better prepared for future flood events.

#### DROUGHT MANAGEMENT AND CLIMATE ADAPTATION

43. RBMPs under the WFD can help address **water scarcity** by identifying drivers and pressures, implementing measures to reduce abstraction pressures, promoting efficient use, and demand management. These measures can contribute to drought resilience and preparedness, aligning with the EU's objectives for sustainable water management and environmental protection.
44. **Drought Management Plans** (DMPs) and other similar strategies and tools are recommended alongside (or as an integral part of) RBMPs to manage drought risks more effectively. DMPs should contain at least three elements: (i) Indicators and thresholds to define the beginning, end, and severity of droughts; (ii) measures to be taken in each phase of a drought to prevent deterioration of the water status and to mitigate negative effects; and (iii) an organisational framework with a transparent governance to deal with drought and subsequent revision and updating of the existing DMPs (feedback loop based on analysing drought impacts).
45. Adaptation measures for water scarcity and droughts should prioritise a **water-smart economy**, integrating the management of all water resources to enhance resilience to climate change and mitigate risks. A **cost-effectiveness analysis** should guide the selection of measures, considering socio-economic and climate scenarios, while

avoiding negative externalities like adverse impacts on environmental flows from water reuse practices.

46. Priority **water allocation mechanisms** during water scarcity need to consider climate change risks and uncertainties. They should prioritise essential needs like drinking water and critical infrastructure while maintaining ecological integrity. Flexibility in defining priorities at different governance levels and stakeholder engagement is vital for effective implementation and adaptation to changing conditions.
47. **Efficient water use** and **pricing** policies should incentivise water conservation and reduce wastage. Allocation decisions must balance economic, social, and environmental considerations, ensuring equitable access to water resources while promoting sustainability and resilience against droughts as well as (seasonal) changes in precipitation characteristics. Regular reviews and stakeholder involvement enhance transparency and accountability in water allocation processes.
48. Integrated water management is also much more than water distribution and water treatment, only. It also involves **land-use** and **land-management** that affect both water quality and quantity. Pressures are often interlinked, including both climate change, land use, economic activities (energy production, industry, agriculture and tourism), urban development and demographic changes. The design of measures in RBMP should therefore be coordinated and spatial planning by Member States should take account of climate change, water scarcity and flood risks. Such an integrated approach to water management becomes even more important as our climate is changing. An **institutionalised process of cooperation** on climate adaptation and water management is needed, as is staff training through capacity-building programmes.

#### NATURE-BASED SOLUTIONS FOR RESILIENCE & CLIMATE ADAPTATION

49. It is recommended to avoid structural changes to water bodies as much as possible, as the best resilience to face climate change is often provided by **preserving or restoring the natural state of ecosystems**. Nature-based solutions (NBS) for making water ecosystems more resilient to climate change offer multifaceted benefits including improved water retention, enhanced biodiversity, and climate change mitigation through carbon sequestration. They promote resilience to climate change impacts, including flooding and droughts, while fostering sustainable communities. NBS also play a crucial role in improving water quality and enhancing hydromorphology. They mitigate the vulnerability of water systems to droughts, providing alternative water access through natural reservoirs. NBS implementation spans across various scales, from large-scale river restorations to localised urban infiltration projects, effectively addressing different flood risks and water management needs.
50. Economic assessments of NBS for flood and drought management have demonstrated **favourable benefit-cost ratios** and highlighted the multiple **co-benefits**. Challenges to

implement NBS remain, including insufficient demonstration of their multiple benefits compared to grey alternatives, limited understanding of their effectiveness against high-risk extreme floods, and scarcity of land adjacent to water bodies for implementation. Additionally, there is a limited mobilisation of finances and inadequate consideration of climate change impacts on NBS functionality and resilience.

#### CROSS-BORDER/TRANSBOUNDARY ASPECTS OF CLIMATE ADAPTATION

51. Transboundary cooperation for climate adaptation involves collaborative efforts among neighbouring countries to address common challenges and opportunities. This collaboration requires navigating conflicting interests and needs while promoting the sharing of data, resources, and expertise. By working together, countries can achieve greater efficiency in adaptation efforts, avoid unintended consequences of unilateral actions (maladaptation), and promote sustainable development and regional integration.
52. Establishing robust **data exchange** mechanisms is essential for enhancing transboundary cooperation in climate resilient water management. By standardising data collection, sharing processes, and information exchange protocols, countries can improve coordination and decision-making on water management issues. International agreements and collaborative platforms facilitate the exchange of crucial information among riparian countries, supporting integrated approaches to water resource management and climate adaptation.
53. Effective management of international water bodies requires **institutional frameworks** and principles of integrated water resource management. Basin-wide agreements provide a foundation for transboundary cooperation, guiding collaborative efforts and promoting harmonisation of methodologies and strategies. By adopting shared approaches to climate adaptation, countries can address common challenges, promote sustainable development, and build resilience to climate change impacts.
54. Implementing adaptation plans necessitates close coordination with other relevant policies and stakeholders. By aligning adaptation efforts with existing policies and engaging stakeholders across sectors, countries can maximise synergies, secure funding, and enhance the effectiveness of adaptation measures. Prioritising actions that benefit the entire basin, sharing costs and benefits, and leveraging local knowledge are essential strategies for successful adaptation while minimising conflicts and vulnerabilities within the basin.

#### HOW TO DO A CLIMATE CHECK OF WFD MEASURES

55. A climate check of measures involves potentially two main steps: **screening the Programme of Measures (PoM)** level and detailed **proofing for individual projects**. Screening assesses climate robustness and a contribution to mitigation and adaptation, ensuring measures align with objectives and climate goals. Detailed proofing integrates

climate change aspects into project development, focusing on mitigation and adaptation. It involves an early assessment of GHG emissions and climate resilience, ensuring projects are compatible with climate targets and are resilient to future impacts.

56. The screening phase evaluates measures relevance, effectiveness, flexibility, and side effects under changing climatic conditions. It considers adjustments needed, safety margins, and coherence with climate adaptation strategies. This ensures measures remain effective and adaptable, contributing to climate resilience while avoiding maladaptation. Screening identifies key areas for further analysis and adaptation planning, guiding decision-making in water management.
57. Detailed proofing integrates climate mitigation and adaptation aspects into project development, aligning with EU climate objectives. It involves assessing GHG emissions and climate resilience, ensuring projects are compatible with climate targets and resilient to future impacts. The process includes early assessment of GHG emissions, considering energy efficiency and mitigation options to reduce the carbon footprint. It also evaluates climate vulnerabilities and risks, identifying and implementing suitable adaptation measures.

## 1 INTRODUCTION

2 EU waters are affected by various human activities, e.g. land use and land use change, water  
3 abstraction, construction of infrastructure, fisheries, the introduction of invasive alien species  
4 and pollution with nutrients and hazardous substances. Those pressures are aggravated by the  
5 growing impacts of climate change, such as faster or prolonged snow melting periods,  
6 shortened groundwater formation periods, warmer soils with increased biological activity that  
7 affects water quality and causes an increase in weather and climate extremes like cloudbursts  
8 and heat waves, as well as more frequent and more severe periods of extreme droughts and  
9 floods<sup>5</sup>. Also, stronger evaporation due to the rise of the average water and air temperature,  
10 seasonal changes in precipitation and sea level have an impact on the biological, ecological,  
11 and chemical status of European water bodies. The damage to the water system generates very  
12 high economic losses. For example, a recent study estimates the economic drought-related  
13 losses in the EU to be 9,4 billion euros each year. In a 3°C global warming scenario, these costs  
14 would rise to 45 billion Euro/year by 2100 (Feyen et al., 2020).

15 Hence, under current and future climate change conditions, it is even more necessary to achieve  
16 sustainable management of European freshwaters, transitional and coastal waters, ensuring  
17 good water quality and access to sufficient quantity for sustainable, balanced and equitable  
18 water use (Article 1, WFD). It is also necessary to adapt to the unavoidable negative  
19 consequences of climate change that will occur even if we reach climate neutrality.

### 20 ***What is the purpose of this guidance?***

21 This guidance document i) updates information on climate change impacts on the water cycle  
22 and ii) provides tools to help water managers align River Basin Management (RBM) planning  
23 under the Water Framework Directive (WFD) and the Floods Directive (FD) to climate  
24 adaptation planning.

25 The WFD (EU, 2000) was adopted 8 years after the UN Framework Convention on Combat  
26 Climate Change (UNFCCC, 1992). Thus, the need to reduce greenhouse gases (GHG) as well  
27 as the impacts of climate change were already well known. Article 1 of the WFD indicates that  
28 one of its purposes is to establish a framework to mitigate the effects of droughts and floods.  
29 However, there is no explicit provision in the Directive on how to take climate change into  
30 account in RBM. One important step to complement the WFD was taken in 2007 with the FD.

31 Two years later, in 2009, [Guidance Document No 24](#), ‘RBM in a Changing Climate’ was  
32 published as part of the Common Implementation Strategy (CIS) of both the WFD and FD.

---

<sup>5</sup> See the Glossary for the definitions.

33 That guidance was a first step in developing a methodology to support Member States (MSs)  
34 in including climate change considerations in their water management in the programmes of  
35 measures (PoM) of the RBM cycles and in the flood risk management cycles.

36 In 2013, the European adaptation strategy encouraged EU MSs to adopt comprehensive climate  
37 adaptation strategies. Between 2013 and 2018, the number of MSs with adaptation strategies  
38 sharply increased from 15 to 25. By 2020, all MSs had prepared such strategies. However,  
39 these varied greatly in scope, delivery, and implementation methods.

40 **In 2021, a new EU strategy for climate adaptation** was adopted to respond to the meanwhile  
41 unavoidable impacts of climate change which require increased adaptation efforts. The  
42 strategy, part of the [European Green Deal](#), aims to accelerate efforts to protect nature, people  
43 and livelihoods against the [impacts of climate change](#). In July 2021, the [European Climate Law](#)  
44 entered into force. The regulation provides for national adaptation strategies and plans  
45 alongside climate adaptation planning at the Union level<sup>6</sup> and formulates expectations  
46 regarding the quality of national adaptation policies and their outcome. In accordance with  
47 Article 7 of [the Paris Agreement](#), the Climate Law also established a “duty to adapt” to ensure  
48 continuous progress in enhancing the adaptive capacity, strengthening resilience and reducing  
49 vulnerability to climate change.

50 **National adaptation strategies of MSs shall take into account particular vulnerabilities of**  
51 **relevant sectors including the “water/soil and food nexus”**. They shall promote Nature-  
52 based Solutions (NBSs) and ecosystem-based adaptation. MSs shall regularly update national  
53 climate adaptation strategies and include the updated information in climate adaptation reports.  
54 The Climate Law also tasks the Commission with regularly assessing the consistency of  
55 relevant national measures with their national adaptation plans and issuing recommendations  
56 if such measures are seen insufficient to reduce climate change vulnerability.

57 In 2021, the Commission adopted new **technical guidance for the “climate-proofing” of**  
58 **infrastructure projects** for the period 2021-2027. This guidance<sup>7</sup> are in line with Article 5 (5)  
59 of the Climate Law, which stipulates that the Commission shall adopt guidelines setting out  
60 common principles and practices for the identification, classification and prudent management  
61 of physical climate risks when planning, developing, executing and monitoring projects and  
62 programmes for projects.

63 In addition, the Commission has published in 2023 **guidelines on Member States’ adaptation**  
64 **strategies and plans**<sup>8</sup>, based on a review of the 2013 guidelines on developing adaptation  
65 strategies. The new guidelines give an overview of features that are essential for (re)crafting

---

<sup>6</sup> Article 5 (2) Regulation (EU) 2021/1119 “*The Commission shall adopt a Union strategy on adaptation to climate change in line with the Paris Agreement and shall regularly review it in the context of the review provided for in point (b) of Article 6(2) of this Regulation*”.

<sup>7</sup> Commission Notice *Technical guidance on the climate proofing of infrastructure in the period 2021-2027* (2021/C 373/01), available for download [here](#).

<sup>8</sup> 2023/C 264/01

66 strong adaptation policies and plans, such as a proper legal framework, regularly updated  
67 adaptation strategies and plans with clear adaptation policy priorities.

68 **There is a virtuous feedback loop between RBM planning and climate adaptation**  
69 **planning.** RBM and flood risk management drive PoMs to improve the water cycle but can  
70 also deliver robust data for national and regional climate adaptation planning. Conversely, the  
71 objectives of national and regional climate adaptation plans should be carefully considered in  
72 river basin and Flood Risk Management Plans (FRMP) to account for climate change.

73 **This feedback loop can, however, be hampered by a mismatch of planning cycles and by**  
74 **lacking coordination between public authorities.**

75 For historical reasons, the planning cycles under the EU Climate Law, the WFD and FD are  
76 not aligned. From 30 September 2023, the reporting cycle is every five years under the EU  
77 Climate Law. Every five years, the Commission shall assess (a) the collective progress made  
78 by all MSs towards achieving the climate-neutrality objective to reduce climate emissions to  
79 net zero by 2050; and (b) the collective progress made by all MSs on climate adaptation. Under  
80 the WFD and FD, the implementation cycles are six years.

81 Moreover, MSs may assign competencies for water management and climate adaptation  
82 planning to different public bodies. As with other areas of public policy, this can lead to  
83 coordination issues and friction within MSs. Moreover, the need to align water and flood risk  
84 management in a transboundary manner can be hampered by diverging views among MSs on  
85 climate adaptation needs. For example, neighbouring countries may have common  
86 groundwater bodies as well as freshwater, estuarine and coastal surface waterbodies. Water  
87 managers in such regions should ideally coordinate water abstraction and water allocation  
88 permits in transboundary regions. This can be difficult in the absence of coordinated MSs for  
89 climate adaptation needs.

90 To achieve the positive feedback loop between climate adaptation and RBM, this guidance  
91 builds on the six-step approach of the Regional Adaptation Support Tool (RAST) to develop  
92 and implement adaption strategies (Climate ADAPT, 2023a).

### 93 *Who is this Guidance intended for?*

94 This Guidance largely addresses practitioners within competent authorities responsible for the  
95 management of surface and groundwater as well as coastal and marine areas. Yet, it is also  
96 meant to assist authorities in dealing with climate change adaptation in a broader context.  
97 Though, equally important, it is meant to inform and guide all stakeholders playing a role in  
98 water management at national, regional, and local levels.

### 99 *What is included in this Guidance?*

100 This guidance provides the most recent scientific findings on interactions between climate  
101 change and water based on models, projections, and scenarios. In addition, it builds on concrete  
102 initiatives and developments included in the European Climate Adaptation Platform [Climate-](#)

103 [ADAPT](#)<sup>9</sup>. It provides a methodology to prepare, implement and monitor actions for adapting  
 104 water management to ongoing and future climate change impacts. These Guidelines are  
 105 structured according to the following chapters:

Chapter 1	Introduces the guidance document
Chapter 2	Gives an overview of current climate modelling and scenarios. It aims to describe the status quo and raise awareness about the urgency of the climate crisis and its main effect on Europe.
Chapter 3	Creates an overview of the WFD and the FD, the most important related documents and other policies with a water-related context.
Chapter 4	Provides an overview of more resilient water management strategies in line with the climate Adaptation Support Tool and the 6-step climate adaptation cycle
Chapter 5	Gives an overview of guiding principles related to climate change and the RBM under the WFD.
Chapter 6	Follows the three steps (PFRA, FHRM and FRMP) of the FD's risk management cycle. It proposes strategies to integrate climate change. Furthermore, it discusses adaptation measures related to the FD.
Chapter 7	Discusses the ability of drought management, climate adaption, the role of RBMP, DMP or other strategies adopted by MSs as supporting tools to address droughts and water scarcity.
Chapter 8	Focuses on Nature-based Solutions and how the restoration and enhancement of ecosystem services can protect society against the negative impacts of climate change in a cost-efficient way.
Chapter 9	Summarises the transboundary aspects of adaptation and provides a guideline to enhance transboundary cooperation in line with a joint vision for climate adaptation needs.
Chapter 10	Discusses how to do a climate check on measures (adaptation and mitigation) based on a screening phase and a detailed proofing of infrastructure projects.

106

## 107 2 CLIMATE MODELLING, PROJECTIONS AND SCENARIOS

### 108 2.1 Observed climate change at the global level

109 The latest IPCC assessment confirms that the rapid warming of the atmosphere, land, oceans,  
 110 and cryosphere results from human-driven increases in greenhouse gases (GHG). Carbon  
 111 dioxide concentrations in the atmosphere continue to rise, already resulting in a 1.09 °C global  
 112 mean temperature increase compared to pre-industrial levels (IPCC, 2022). A mean  
 113 temperature increase of 1.5°C and 2 °C is likely to occur this century without significant  
 114 emission reductions. This was highlighted by the record year 2023, in which the global average  
 115 temperature was around 1.45 °C above pre-industrial levels as well as above 1.5 °C in the last  
 116 12 months since February 2023 (EEA, 2024). Irreversible changes are already happening,  
 117 particularly in oceans, ice sheets, and sea levels (IPCC, 2022). Keeping the temperature  
 118 increase to 1.5 °C would require a cut in global GHG emissions of 43% by 2030 compared to

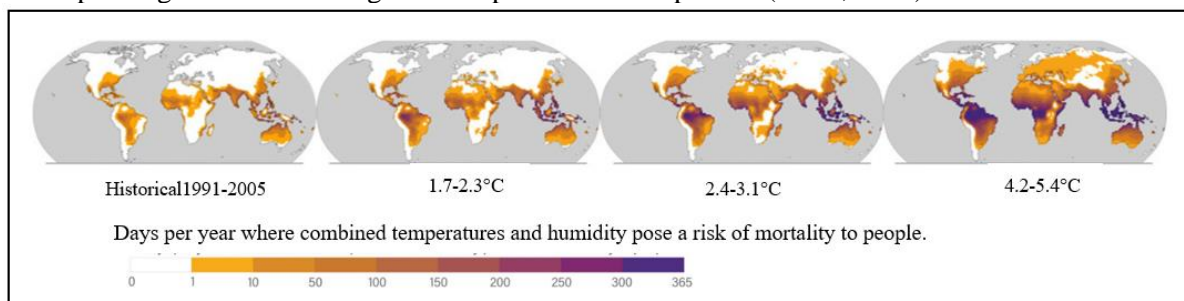
---

<sup>9</sup> The MSs are at different stages of preparing, developing, and implementing NASs and NAPs. [Climate-ADAPT](#) prepares an overview of each country's reporting along with links to the public submission of the documents. The reporting follows a consistent structure starting with a summary; assessments of e.g. climate modelling, projections, scenarios, methods and tools; legal and policy frameworks; strategies plans and goals; monitoring and evaluation methodology; good practice, cooperation and synergies; and contacts.

119 2010. Instead, emissions are expected to continue rising to about 10% above 2010 levels.  
 120 Current policies point to a 2.8 ° C temperature rise by the end of the century, and  
 121 implementation of all COP26 pledges would only reduce this to a 2.4-2.6 ° C temperature rise  
 122 (UNEP, 2022).

123 The temperature rise has already led to or will most likely lead to the following impacts:

- 124 i. More frequent and intense weather extremes, including heatwaves, heavy precipitation, droughts,  
 125 and cyclones, are observed globally. There is also a trend to hotter extremes and reduced cold  
 126 extremes since the 1950s.
- 127 ii. Water-related risks and hazards will grow, with higher global warming levels posing greater threats.  
 128 Water management challenges will intensify, especially in resource-constrained regions, due to the  
 129 magnitude and speed of future climate change.
- 130 iii. Climate change-triggered extreme events are pushing natural and human systems beyond their  
 131 adaptive capacities, causing widespread adverse impacts and damages. The figure below gives an  
 132 overview of in which areas people will be exposed to deadly heat and humidity conditions  
 133 depending on the different global temperature developments (IPCC, 2022).



134  
 135 *Figure 1: Projected development of areas where people will be exposed to possible deadly heat and humidity conditions (IPCC,*  
 136 *2022).*

## 137 2.2 Climate Change observations and projections for the EU and their impacts

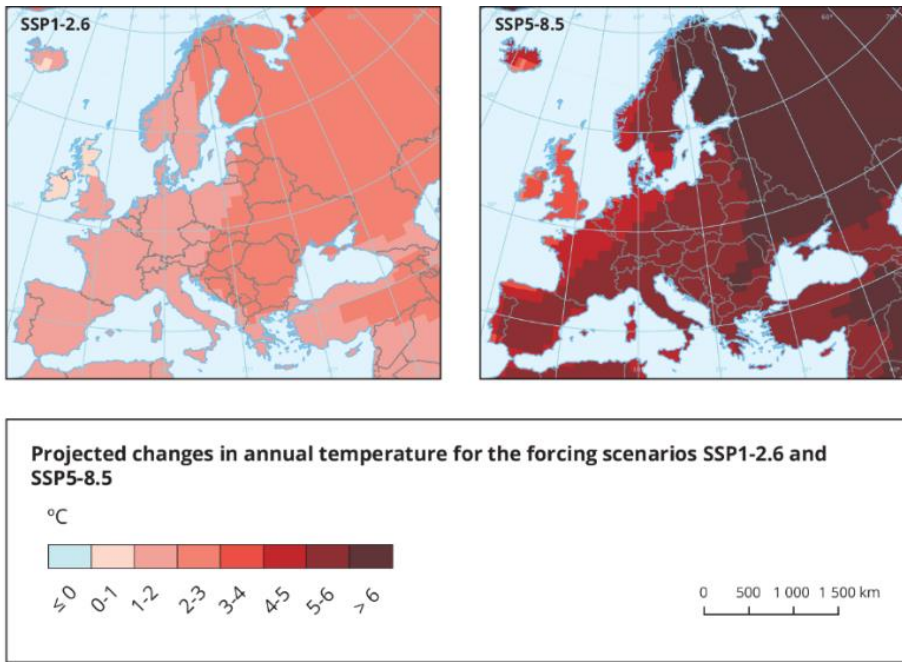
138 Europe is the fastest-warming continent in the world (EEA, 2024), rising already by 1.94 to  
 139 2.01 °C on average from 2010-2020 compared to pre-industrial levels. The warmest years have  
 140 occurred in the past decade, with winters getting milder and summers hotter and recurrent  
 141 severe extremes such as drought, heatwaves, and floods (IPCC, 2022).

142 Extremely hot weather events are set to intensify across Europe under all emissions scenarios.  
 143 Critical warming thresholds, especially beyond 2 °C, could lead to severe impacts on  
 144 ecosystems and humans, particularly in southern regions, due to the extreme heat, water  
 145 scarcity, drought, and forest fires (IPCC, 2022). Europe will experience more intense and  
 146 frequent weather and climate extremes, including droughts and flash floods. While complex  
 147 extremes and disasters with cascading effects will emerge.

148 The ongoing temperature increase in Europe is projected to continue throughout the 21st  
 149 century under all scenarios. Surface temperature is projected to increase by 1.3-3.4 °C under  
 150 SSP1-2.6<sup>10</sup> and by 4.1-8.5 °C under SSP5-8.5. Climate change projections reveal regional  
 151 differences in Europe, e.g., as the highest temperature increases are expected in north-eastern  
 152 Europe and Scandinavia during winter and in southern Europe in summer (EEA, 2019).

---

<sup>10</sup> SSP: Shared Economic Pathway



153

154 *Figure 2: Projected changes in near-surface air temperature under different SSP emission scenarios (SSP1-2.6 and SSP5-8.5)*  
 155 *in Europe (°C) when comparing the reference periods 1981-2010 and 2081-2100. Source: EEA website using data from*  
 156 *CMIP6. This data was used in the IPCC AR6 report.*

157 The main impacts on the EU water resources are summarised in Table 1 to provide an overview  
 158 of the expected water-related changes in different parts of Europe, followed by a more detailed  
 159 description.

160 *Table 1: Expected change of water-related hazards in Europe (IPCC, 2022; EEA, 2021)..*

<i>Hazard</i>	<i>Indicator</i>	<i>Northern Europe</i>	<i>Central Europe</i>	<i>Southern Europe</i>
<i>Precipitation</i>	Total precipitation	Annual ↗	Annual ↘	Annual ↘
		Summer ↘	Summer ↘	Summer ↘
	Maximum consecutive 5-day precipitation	↗	↗	↗
	Extreme precipitation total	↗	↗	↗
	Frequency of extreme precipitation	↗	↗	↗
<i>River Floods</i>	River flood index using runoff	↘	↗	↘
	<i>Aridity</i>	Aridity actual	↗	↘
<i>Drought</i>	Consecutive dry days	→	↗	↗
	Frequency of meteorological droughts	↗	↗	↗
	The magnitude of meteorological droughts	↗	↗	↗
	Frequency of soil moisture droughts	↗	↗	↗

*Legend:*

↗ | Increase throughout most of a region

↘	Decrease throughout most of a region	161
↔	Increase as well as decrease in a region	
→	No significant changes from the current situation	102

### 163 Changes in annual precipitation and water flow

- 164 i. In the recent past, annual precipitation has not shown a clear significant trend in Europe, although  
 165 seasonal tendencies have been detected. In the future, summer precipitation is expected to decrease  
 166 in most of Europe (except its Northernmost part). Winter precipitation is projected to increase in  
 167 Northern Europe and decrease in the Mediterranean region. Changes in precipitation type,  
 168 particularly snowfall, will also have implications for river flow (IPCC, 2022). European countries  
 169 are also experiencing an increased share of their annual precipitation falling during heavy rain  
 170 events (EEA, 2021).

*Example 1: Glacier melt in the Alps.*

The flow of the glacier-fed rivers Rhine, Rhone, Danube and Po is still showing some continuity related to glacier melting. This part of their base flow is relatively growing during heat waves. Before 2100 and in the eastern parts of the Alps already before 2050, the glaciers will have vanished and so will the base flow related to this. This means a substantial change for the glacier-fed rivers towards a rainfed river plus a substantial reduction of their flow (BRLi, 2023).

171

### 172 Floods

- 173 ii. Various indices of heavy precipitation point to a future increase in such events in Europe, especially  
 174 in its northern part which has been already experiencing an increasing trend (EEA, 2021).  
 175 iii. Fifty-year river flood levels are projected to increase across most of Europe, especially in central  
 176 and central-eastern Europe. Expected changes in southern Europe are more varied and uncertain.  
 177 Floods related to intense precipitation and excessive soil moisture are expected to increase (IPCC,  
 178 2022).

### 179 Aridity

- 180 iv. Aridity is currently highest in the southernmost regions of Europe, and it generally tapers off  
 181 towards the north. Broadly, Europe is likely to experience more aridity in the future, especially in  
 182 areas just north of the current 'aridity hotspots' (the northern part of the Iberian Peninsula, Turkey  
 183 and the Balkans) (EEA, 2021).

### 184 Droughts

- 185 v. Due to enhanced evaporation, a drying trend in Europe as a whole has accelerated during recent  
 186 decades, which is strongest in southern and central-eastern Europe. Hydrological droughts have  
 187 increased in southern Europe and in spring and summer for western and northern Europe (EEA,  
 188 2024).  
 189 vi. Future changes in droughts vary depending on the season. In winter, the frequency of drought is  
 190 expected to increase in the Mediterranean region, while decreases are projected in most of the other  
 191 European regions. In all the other seasons, and especially in summer, the frequency and severity of  
 192 drought events are expected to increase (IPCC, 2022).  
 193 vii. Soil moisture content has significantly dropped in southern Europe and increased in parts of  
 194 northern Europe; this trend is projected to continue with a decline in the top-soil moisture content  
 195 that will affect Europe (IPCC, 2022).

196viii. The duration of dry spells has been largely stable throughout Europe so far. For the future, large  
 197 increases are projected for southern Europe, smaller increases for central Europe and no significant  
 198 changes for northern Europe (EEA, 2021).

### 199 **Sea level rise and extreme sea level**

200 ix. Globally, mean sea levels - the height of seawater relative to land - have been rising for more than  
 201 a century, with accelerating rates in recent decades due to warming oceans and melting glaciers and  
 202 ice sheets (EEA, 2021).

203 x. The relative sea level of Europe's seas will continue to rise throughout this century under all  
 204 emissions scenarios. Under a high-emissions scenario, the rise is expected to be greater than 0.60 m  
 205 along most of the European coastline. The only exception is the Northern Baltic Sea, where current  
 206 coastal floods are projected to become rarer because of continued land uplift following the last ice  
 207 age (EEA, 2021).

### 208 **Water temperature**

209 xi. River temperatures face increases in median values between 1.3 °C and 3.8 °C (van Wesenbeeck et  
 210 al., 2021)). Lake surface temperatures are warming at a rate of 0.33 °C per decade, which is faster  
 211 than the global rate of 0.23 °C per decade (EEA, 2024). Increasing water temperature leads to higher  
 212 evaporation rates, resulting in reduced water volumes in lakes worldwide (Zhao, Li, Zhou, & Gao,  
 213 2022). Global annual mean lake evaporation rates are projected to rise by 16% by 2100, impacting  
 214 lake levels and surface water extent (Woolway, et al., 2020). The sea surface temperature has  
 215 increased since 1980 by 0.5°C globally and around 1.1°C for Europe and have reached  
 216 unprecedented levels in 2023 (EEA, 2024).

## 217 **2.3 Impact on water body status**

218 The key objective of the WFD is to achieve both good chemical and ecological status, the latter  
 219 an expression of the quality of the structure and functioning of aquatic ecosystems that includes  
 220 biological, physiochemical and hydromorphological parameters. The changes caused by  
 221 climate change, as described in the previous chapter, have an impact on the ecosystems in  
 222 different ways.

### 223 **Changes in annual precipitation and water flow**

224 i. The hydro morphological character of waterbodies will be altered by changing precipitation patterns  
 225 including less snowfall and retention will reshape the annual hydrograph which will degrade  
 226 biological communities through scouring or desiccation, reducing biodiversity and lowering  
 227 ecological status (IPCC, 2022). Alteration of river flow, also through engineering responses, will  
 228 have serious consequences on processes such as sediment provision and transport, altering  
 229 waterbody morphology and physical habitats. This will lead to changes in species composition  
 230 successively reducing resilience with climate change progression (O'Briain, 2019).

### 231 **Floods**

232 ii. Flooding or more frequent summer storms can deliver heavy nutrient loads from agricultural land  
 233 to lakes and rivers during short time intervals and can also cause more storm overflows in urban  
 234 wastewater distribution systems, estimated to increase by 37% in volume for a high emissions  
 235 scenario (Abdellatif, et al., 2015). Also, slope mass movements", caused by extreme weather events  
 236 might increase (Stoffel, Tiranti, & Huggel, 2014).

### 237 **Aridity and droughts**

238 iii. Increased evaporation and reduced flow lead to less dilution of nutrients, especially in rivers  
 239 receiving urban wastewater and diffuse pollution from agricultural areas. Concentrations of  
 240 phosphorus and ammonium have been predicted to double with climate change in Mediterranean

241 rivers during low-flow months (Dorado-Guerra, et al., 2023). Droughts also favour salt-water  
 242 intrusions in coastal areas with irrigation linked to increasing salinity in river basins (Thorslund, et  
 243 al., 2021).

#### 244 **Sea level rise and extreme sea level**

245 iv. An unavoidable drawback of the strong rise in sea levels and the consequent need for adaptation is  
 246 that in about 25% of the coastline of the EU, the sea would be disconnected from the hinterland by  
 247 natural or physical barriers (Feyen et al., 2020).

248 v. The spatially averaged median value of sea level rise driving potential shoreline retreat of sandy  
 249 beaches in Europe by 2100, relative to the baseline year 2010, is projected to be about 97 m under  
 250 a high emission scenario and 54 m under a medium emission scenario. These hotspots include  
 251 regions along the Italian Adriatic coast, the French Atlantic coast, the east part of the Baltic Sea and  
 252 around the North Sea (Athanasiou, et al., 2020).

253 vi. With some limitations to the data, historical once-in-a-hundred-years coastal floods are projected  
 254 to occur several times a year on the Mediterranean Sea and the Black Sea coasts, at least once a  
 255 year along most other European coasts under a high-emissions scenario and at least once a decade  
 256 along the remaining European coasts even under lower emissions scenarios (EEA, 2021).

257 vii. The rising sea level leads to the salination of freshwater sources that many coastal areas use for  
 258 their drinking water (IPCC, 2019)

259viii. Tidal marshes depend on a sufficient sediment load to cope with sea level rise and to allow accretion  
 260 and a tidal range, but many are likely to become sub-tidal by the end of the century. Migration of  
 261 zones landward is possible if this is not blocked by natural or anthropogenic barriers (Short, et al.,  
 262 2016).

#### 263 **Water temperature**

264 ix. Increasing water temperature can have a direct physiological response in biota increasing  
 265 respiration, while the increasingly frequent pattern of heatwaves followed by colder low-pressure  
 266 systems can cause metabolic disruption, potentially inducing fish kills (Jeppesen, et al., 2021).

267 x. Warmer temperatures can lead to altered stratification regimes in lakes and transitional and coastal  
 268 waters altering nutrient cycling and isolating lower layers from the atmosphere reducing oxygen  
 269 (Rogora, et al., 2018). Seasonal mismatch is already occurring with alteration to the traditional start,  
 270 length and end of seasons altering species phenology resulting in a mismatch between prey and  
 271 predators, with implications across ecosystems (IPCC, 2022).

272 xi. Geochemical parameters and processes will also be increasingly affected by warmer temperatures  
 273 and an increased soil moisture deficit has been predicted to lead to an increase in the mineralisation  
 274 of nitrogen by over 30% following rewetting (McAlee, et al., 2022) and together with changes in  
 275 land use and hydrology has already been blamed for increasing Nitrogen export to the Baltic (Räike,  
 276 Taskinen, & Knuuttila, 2020).

### 277 **2.4 Socio-economic impacts on water-dependent sectors and society**

278 Water-related activities in Europe use around 243 billion m<sup>3</sup> of water annually. Within the EU  
 279 agriculture accounts for the largest share of water use with around 40% of the total water used  
 280 per year, followed by 28% for energy production, 18% for mining and manufacturing and 12  
 281 % for household use. These values vary significantly across Member States (EEA, 2018). More  
 282 than half of the water used (over 140,000 billion cubic meters) is returned to the environment  
 283 but it then often contains impurities or pollutants, including hazardous chemicals. Climate  
 284 change and the more frequent occurrence of hazards will have an impact on the economy and  
 285 its sectors.

#### 286 **Economic losses**

- 287 i. Between 1980 and 2022, climate-related extremes reached estimated losses of about 650 billion  
 288 Euros in the EU. Hydrological hazards (floods) account for almost 43% and meteorological hazards  
 289 (storms, including lightning and hail, together with mass movements) for around 29% of the total.  
 290 As for the climatological hazards, heat waves caused around 20% of the total losses while the  
 291 remaining approx. 8% is associated with droughts, forest fires and cold waves together (EEA,  
 292 2023b).
- 293 ii. The European Insurance and Occupational Pensions Authority's Pilot dashboard on insurance  
 294 protection provides a comprehensive view of the protection gap, revealing that merely 35% of the  
 295 overall losses resulting from extreme weather and climate-related events in Europe are covered by  
 296 insurance (EIOPA, 2019).
- 297 iii. **Droughts:** Without climate mitigation and adaptation actions, total drought losses for the EU and  
 298 the UK would increase to at least 45 billion Euros each year in a 3 °C warming scenario compared  
 299 to about 9 billion Euros/year at present (Feyen et al., 2020)). The number of people in Europe living  
 300 in areas with water resources under stress will increase to 65 million in a 3 °C warming scenario  
 301 and the people living under severe water stress, now around 3.3 million, would become fourfold in  
 302 a 3 °C warming scenario. In some parts of southern Europe, practically all available water will be  
 303 used in the summer months, and the majority of people and economic activities in these regions  
 304 will face water scarcity (Feyen et al., 2020)).
- 305 iv. **Floods:** If no mitigation and adaptation measures are taken, economic losses will grow to nearly 50  
 306 billion Euros a year with 3°C global warming by 2100 and 482 million Europeans due to river  
 307 flooding, compared to 7.8 billion Euros/year and 172 billion Euros/year at present (Feyen et al.,  
 308 2020).
- 309 v. **Coastal floods:** Annual damage from coastal flooding is projected to increase from 1.4 billion  
 310 Euros/year to 240 billion Euros/year by 2100 with no mitigation and adaptation measures taken and  
 311 can expose up to 2.2 million people each year (Feyen et al., 2020).

## 312 **Agriculture**

- 313 vi. Rising temperatures, altered precipitation patterns, and increased climate extremes will result in  
 314 increased drought-driven yield losses and flood-related risks to agricultural production, with  
 315 potential implications for food safety and security (IPCC, 2022).

## 316 **Industry, energy and waterborne transport**

- 317 vii. The future is likely to witness a substantial rise in freshwater demand for energy and industrial  
 318 sectors globally, leading to increased competition for water resources across sectors. Although  
 319 climate change also poses challenges to water-intensive industries like mining, quantifying these  
 320 risks remains difficult due to limited research and data (IPCC, 2022).
- 321 viii. Recent modelling suggests that the European energy sector could be subject to stress in extreme  
 322 drought scenarios. The European energy system is a major water user except for wind and solar  
 323 power, as water is required for hydropower generation, but also for plant cooling in thermoelectric  
 324 production and bulk transport (of coal) on major rivers.
- 325 ix. Climate change represents a significant safety and business continuity risk to waterborne transport  
 326 operations and infrastructure – and hence to local, national and regional economies. Seaports are  
 327 exposed to sea level rise and extreme weather, including storms, changes in wind speed or direction  
 328 and significant wave heights (IPCC, 2022).
- 329 x. Inland waterways are particularly susceptible to changes in seasonal precipitation (both rain and  
 330 snow) as well as glacier melt because these phenomena dictate the frequency and severity of  
 331 extreme high and low flow conditions (PIANC, 2020).
- 332 xi. In terms of economic losses, the interruption in the logistics chains caused by the low-water event  
 333 in 2018, caused considerable economic losses which, for example, resulted in a decrease in German  
 334 industrial production by almost 5 billion Euros (CCNR, 2021).

## 335 **Public water supply and tourism**

- 336 xii. Recent modelling suggests that the demand for public water supply in Europe may increase by up  
 337 to 10% with strong regional variations. The highest extra abstractions will occur in the most water-  
 338 rich countries (Scandinavia) which quite likely will have enough water to cope with such extra  
 339 abstractions. Slightly elevated values (up to 5% extra abstractions) are also expected in dry southern  
 340 regions where such extra demands may, however, come close to the maximum supply of freshwater  
 341 resources, meaning that there may be less room for extra abstractions.
- 342 xiii. In some MSs, rivers and coasts support water-based tourism and recreation activities that  
 343 significantly contribute to the socio-economic (employment) and/or health and well-being status.  
 344 Changes in the frequency and severity of high and low flow conditions, sea level rise and sediment  
 345 dynamics will affect these activities. Changes in physio-chemical conditions, like environmental  
 346 quality deterioration due to nutrient enrichment, or water temperature increases will lead to changes  
 347 in vegetation growth rates, species' range shifts, and invasions of alien species.

### 348 3 WATER AND CLIMATE CHANGE – EU POLICY FRAMEWORK

#### 349 The EU **Water Framework Directive** and the **Floods Directive**

- 350 i. [Water Framework Directive](#) (2000): The WFD established a legal framework to protect and  
 351 restore the water environment across Europe by 2015 to ensure the long-term sustainable use  
 352 of water. MSs were allowed to prolong the implementation time if justified, but the WFD  
 353 objectives should be achieved by 2027 at the latest.
- 354 a. [6th WFD and FD Implementation Report](#) (2021): While a large majority of  
 355 groundwater bodies have achieved a good status, less than half of surface water bodies  
 356 are at a good status, even though the deadline for achieving this was 2015, except for  
 357 duly justified cases.
- 358 b. [Fitness check](#) (2019): The report has concluded that the WFD has been largely  
 359 successful in setting up a governance framework for integrated water management for  
 360 more than 110,000 surface water bodies in the EU, slowing down the deterioration of  
 361 water status and reducing chemical pollution. Still, the fitness check reported that  
 362 additional efforts are needed in many MSs.
- 363 ii. [Floods Directive](#) (2007): The FD established a legal framework for the assessment and  
 364 management of flood risks across MSs, aiming to reduce the adverse consequences of floods  
 365 to human health, the environment, cultural heritage, and economic activities by developing  
 366 PFRA, FHRM and a FRMP.

#### 367 EU **Water Scarcity** and **Drought Policy**

- 368 i. [Addressing the challenge of water scarcity and droughts in the European Union](#) (2007): The  
 369 report identified key policy options for addressing water quantity management, including  
 370 options related to 'putting the right price tag on water', 'allocating water more efficiently' and  
 371 'fostering water efficient technologies and practices'.
- 372 ii. [Blueprint for Safeguarding European Waters](#) (2012): The report notes that limited progress has  
 373 been achieved in implementing the policy instruments identified in 2007. As a follow-up and  
 374 to enforce good water management, several Guidance documents were adopted under the [CIS](#)  
 375 (e.g. on ecological flows and water balances).
- 376 iii. [European Green Deal](#) (2019) and related policies:
- 377 a. [Circular Economy Action Plan](#) (2020): The plan emphasises acceleration for water  
 378 reuse and efficiency, including in industrial processes.
- 379 b. [Regulation on minimum requirements for water reuse for agricultural irrigation](#) (2020).
- 380 c. [Guidelines to support the application of Regulation 2020/741 on minimum](#)  
 381 [requirements for water](#) (2022): The guidelines should support the application of the  
 382 regulation on the general and administrative obligations, its scope of application, and

- 383 its technical aspects, such as risk management and validation monitoring, as well as  
 384 several practical examples.
- 385 iv. [Biodiversity Strategy for 2030](#) (2020): It sets out a commitment to legally protect a minimum  
 386 of 30% of the land, including inland waters, and 30% of the sea in the EU, of which at least one  
 387 third should be under strict protection. Part of the objective is the restoration of at least 25,000  
 388 km of free-flowing rivers, including the removal of primarily obsolete barriers and the  
 389 restoration of floodplains and wetlands.
- 390 d. [Nature Restoration Law](#) (2023): Set binding targets to restore damaged ecosystems and  
 391 bring nature back across Europe. Altogether, these restoration measures should cover  
 392 at least 20% of the EU's land and sea area by 2030, and all ecosystems in need of  
 393 restoration by 2050.
- 394 e. The Proposal for a Forest Monitoring Directive/Regulation (to be adopted soon) and  
 395 the [Forest Strategy 2030](#) (2021): The strategy sets a vision and concrete actions to  
 396 improve the quantity and quality of EU forests and strengthen their protection,  
 397 restoration and resilience.
- 398 f. The Proposal for a Soil Monitoring and Resilience Directive (2023) and [Soil Strategy](#)  
 399 [2030](#) (2021): Provide a framework and concrete measures to protect and restore soils  
 400 and ensure sustainable use. To achieve healthy soils and aquatic ecosystems it is  
 401 essential to coordinate water and soil policies through better soil and water  
 402 management, across borders, and reduce the impact of floods and droughts on people  
 403 and economy.
- 404 v. [EU Strategy on Adaptation to Climate Change](#) (2021): The strategy aims to realise the vision  
 405 that in 2050, the EU will be a climate-resilient society, fully adapted to the unavoidable impacts  
 406 of climate change. To achieve reinforced adaptive capacity and minimised vulnerability to  
 407 climate impacts, adaptation will be made smarter, more systemic, swifter, and by stepping up  
 408 international action. The Commission will help to close knowledge gaps on climate impacts  
 409 and resilience, including on ecosystems, both on land and in the oceans. It promotes  
 410 mainstreaming adaptation into various policy areas and will support improving adaptation  
 411 strategies and plans, as well as promote NBS for adaptation. The Commission also committed  
 412 to help ensure a climate-resilient, sustainable use and management of water across sectors and  
 413 borders by improving the coordination of thematic plans and other mechanisms, such as water  
 414 resource allocation and water permits. It will also help reduce water use by encouraging water  
 415 efficiency and saving, by promoting the wider use of DMP as well as sustainable soil  
 416 management and land-use. This strategy coincided with the implementation of the European  
 417 Climate Law which implements the Paris Agreement's objectives<sup>11</sup>.
- 418 vi. [European Climate Law](#) (2021): It sets into legislation the goal for Europe's economy and  
 419 society to become climate neutral by 2050. It also sets the intermediate target of reducing net  
 420 GHG emissions by at least 55% by 2030, compared to 1990 levels. It also includes strong  
 421 provisions on adaptation to climate change, such as the requirement that relevant EU  
 422 institutions and the MSs 'ensure continuous progress in enhancing adaptive capacity,  
 423 strengthening resilience and reducing vulnerability to climate change'. MSs shall in their  
 424 national adaptation strategies and plans, among others, consider the particular vulnerability of  
 425 the relevant sectors, inter alia, of water and food systems, and promote nature-based solutions.
- 426 vii. [Communication on Managing Climate Risks](#) (2024): It responds to the first ever [European](#)  
 427 [Climate Risk Assessment](#) (2024). The communication sets out how the EU and its Member

---

<sup>11</sup> The [Paris Agreement](#) is the legally binding international treaty on climate change adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015. The Paris Agreement entered into force on 4 November 2016 and is binding for the Member States of the European Union. Since 2019, it forms the basis for implementation meetings of the Conference of the Parties (COP) for the United Nations Framework Convention on Climate Change (UNFCCC).

428 States can better anticipate, understand, and address growing climate-related risks. It sets out  
 429 EU actions in the main impact clusters: natural ecosystems, water, health, food, infrastructure  
 430 and the built environment, and the economy.

431 Other relevant EU policies and legislation

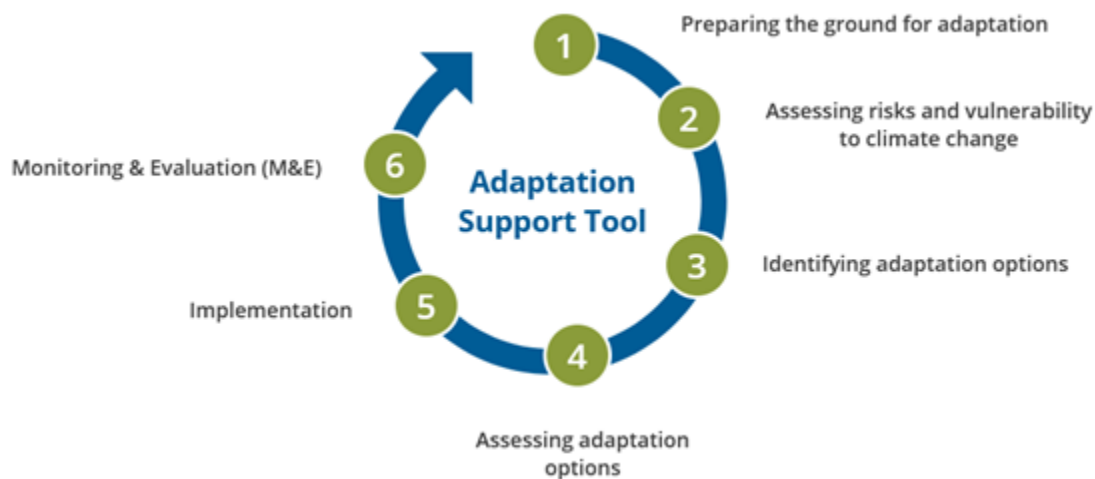
- 432 i. [Strategic Foresight Report](#) (2023): An annual report published by the Commission, giving  
 433 insights into trends, risks, emerging issues and their potential implications and opportunities to  
 434 support strategic planning, policymaking, and preparedness.
- 435 ii. [EU regulation on land, land use change and forestry](#) (2023): The regulation addresses the land  
 436 use sector's impact on the EU's climate goals up to 2030. A novel approach separates the land-  
 437 based net carbon removal target, requiring a reduction of 310 million tonnes of CO<sub>2</sub> equivalent  
 438 by 2030.
- 439 iii. [Renewable Energy Directive](#) (RED III) (2009): It establishes a common framework to promote  
 440 energy stemming from renewable sources in the EU and sets a binding target of 42,5 % for the  
 441 overall share of energy consumption to come from renewable sources in the EU's gross final  
 442 consumption in 2030. The [proposal for the amendment of the Directive](#) proposes that, in the  
 443 permit-granting process, the planning, construction and operation of plants for renewable  
 444 energy production, their connection to the grid and the related grid itself and storage assets are  
 445 presumed as being in the overriding public interest and serving public health and safety when  
 446 balancing legal interests in the individual cases for the purposes of ..., Article 4(7) of Directive  
 447 2000/60/EC...'
- 448 iv. [REPowerEU](#) (2022): With this plan, the EU wants to fight climate change and end its  
 449 dependence on Russian fossil fuels. In order to tackle slow and complex permitting for major  
 450 renewable projects, using energy from renewable sources should be considered as an overriding  
 451 public interest. Dedicated 'go-to' areas for renewables should be put in place by MSs with  
 452 shortened and simplified permitting processes in areas with lower environmental risks.
- 453 v. [Drinking Water Directive](#) (2021): This Directive is related to the WFD and includes a risk-  
 454 based approach throughout the entire drinking water supply chain. This requires risk assessment  
 455 and risk management of catchment areas for abstraction points of drinking water sources and  
 456 for the supply system.
- 457 vi. [Urban Waste Water Treatment Directive](#) (2022): The revision of the directive aims to  
 458 modernise standards, reduce pollution, improve water quality, and enhance access to sanitation  
 459 across the EU. By enforcing stricter regulations, monitoring pathogens, and addressing  
 460 micropollutants, the EU seeks to achieve significant environmental and public health benefits  
 461 while promoting a more sustainable and circular wastewater management sector.
- 462 vii. [Common Agricultural Policy, CAP](#) (2021): The CAP aims to support farmers and improve  
 463 agricultural productivity, ensuring a sustainable and stable supply of affordable high-quality  
 464 food, supporting EU farmers in making a reasonable living, helping to tackle climate change  
 465 and the sustainable management of natural resources, to maintain rural areas and landscapes  
 466 across the EU and keep the rural economy alive by promoting jobs in farming, agri-food  
 467 industries and associated sectors.
- 468 viii. [Marine Strategy Framework Directive](#) (2008): The Directive was put in place to protect marine  
 469 ecosystems and biodiversity upon which our health and marine-related economic and social  
 470 activities depend and further support EU countries achieve good environmental status.
- 471 a. [Action Plan 'Protecting and restoring marine ecosystems for sustainable and resilient  
 472 fisheries'](#) (2023): The action plan aims to use synergies between the EU fisheries and  
 473 environmental law. In doing so, it aims at improving fisheries' sustainability and better  
 474 protecting marine ecosystems and habitats, including supporting them in the process of  
 475 adaptation to climate change.

- 476 ix. [Trans-European Transport Network](#) (2013): The policy addresses the implementation and  
 477 development of a Europe-wide network of railway lines, roads, inland waterways, maritime  
 478 shipping routes, ports, airports and railroad terminals.
- 479 x. [NAIADES III](#) (2021): The core objectives of this 35-point action plan are to boost the role of  
 480 inland waterway transport, shift more cargo to Europe's rivers and canals and facilitate the  
 481 transition to zero-emission barges by 2050.
- 482 xi. [EU Taxonomy Climate and Environment Delegated Acts](#) (2022 and 2023): The acts aim to  
 483 support sustainable investments by clarifying which economic activities most contribute to  
 484 meeting the EU's climate and environmental objectives.
- 485 xii. [Environmental Crime Directive](#) (2008): The directive aims at supplementing existing  
 486 administrative sanction systems with criminal law penalties to strengthen compliance with the  
 487 laws for the protection of the environment. In 2021, the Commission revised the directive and  
 488 adopted a [new version](#) aiming to improve the effectiveness of criminal investigation and  
 489 prosecution.
- 490 xiii. [Sustainable and Smart Mobility Strategy](#) (2020): The strategy aims to deliver a 90% cut in  
 491 emissions by 2050. As part of this strategy, transport by inland waterways and short-sea  
 492 shipping needs to increase by 25% by 2030.
- 493 xiv. [Nitrate Directive](#) (1991): The directive addresses the improvement of water quality and the  
 494 protection of water against nitrates pollution derived from agricultural sources.

#### 495 4 TOWARDS RESILIENCE FOR WATER MANAGEMENT UNDER 496 CLIMATE CHANGE

497 Resilience in general describes the capacity of a social-ecological system to withstand shocks  
 498 without collapsing, to recover, reorganise and transform in anticipation of future stressors  
 499 (IPCC, 2022). Climate adaptation is crucial for resilience in the context of water systems, as it  
 500 shows that stressors were experienced or trends determined, lessons were learnt, flexibility  
 501 despite uncertainty, and stability of the system are worked towards. To help increase resilience,  
 502 the EEA, the MS, and the Commission have developed a Regional Adaptation Support Tool  
 503 ([RAST](#)). The tool is based on a six-step approach to establish and implement climate adaptation  
 504 strategies and plans. The approach can also help to identify and evaluate options such as water  
 505 protection, infrastructure improvements, and changes in water allocation practices.

506 There is a connection between the pressures of climate change on water quality and quantity  
 507 and other anthropogenic pressures. The impact of climate change on water depends on the  
 508 development of other anthropogenic pressures. Ideally, the different analyses outlined in the  
 509 RAST should be integrated within the analysis needed to produce the RBMP and the  
 510 programme of measures.



511  
 512 *Figure 3: Six-step approach of the RAST for the development and implementation of adaptation strategies (Climate ADAPT,*  
 513 *2023a).*

514

#### 515 4.1 STEP 1: Preparing the ground for adaptation by Strengthening Adaptive 516 Capacity

517 Step 1 of the Adaptation Support Tool must be understood as the introduction of key elements  
 518 important to build the basis for a successful adaptation process. This is often linked to other  
 519 factors related to increasing the adaptive capacity.

520 Adaptive capacity in accordance with IPCC AR6<sup>12</sup> is the ability of systems, institutions,  
 521 humans and other organisms to adjust to potential damage, to take advantage of opportunities,  
 522 or to respond to consequences. Building adaptive capacity and increasing resilience in the  
 523 context of water management (including flood, water scarcity and drought risk management)  
 524 requires to:

- 525 i. Understand climate-related risks and collect data to improve decision-making and the  
 526 development of a tailored and sustainable adaptation strategy.
- 527 ii. Establish financial mechanisms (e.g., climate change resilience fund) to support and  
 528 promote the implementation of adaptation measures.
- 529 iii. Identify stakeholders and decide on approaches to engage partners.
- 530 iv. Work in cross-sectoral partnerships and across administrations.
- 531 v. Integrate cross-sectoral adaptation measures and coordination activities with land-use  
 532 planning.
- 533 vi. Include climate change impacts in the RBD awareness-raising activities as part of the WFD  
 534 and FD public participation processes.
- 535 vii. Establish staff training and capacity-building programmes on climate change.
- 536 viii. Develop joint or coordinated adaptation strategies in transboundary RBDs.
- 537 ix. Communicate to stakeholders about climate change and related economic costs in no-jargon  
 538 language that can be easily understood.

---

<sup>12</sup> The Intergovernmental Panel on Climate Change regularly publishes reports about the state of scientific, technical, and socio-economic knowledge on climate change with the latest called Assessment Report 6.

539 x. Ensure communication and coordination on climate change adaptation issues between  
540 different governance levels, geographical areas and policy areas of management within a  
541 RBD.

542 xi. Perform regular evaluations of the adaptation measures and if needed redefine them.

543 A broad range of stakeholders needs to be involved in adaptation mainstreaming efforts,  
544 ranging from national government ministries to sectoral authorities, sub-national governments,  
545 industries, and civil society. Stakeholder involvement helps to ensure that policies are informed  
546 by practical knowledge and on-ground experience.

547 It is crucial to provide accurate information and involve stakeholders at an early stage to co-  
548 design related policy instruments to face the upcoming challenges in the water sector (Hofman,  
549 2015). This includes policies and strategies aiming to promote more sustainable economies and  
550 societies in general but also sectoral policies on, e.g., agriculture, energy, transport and urban  
551 as well as spatial planning.

552 As part of integrated RBM, an important part of adaptive capacity building under STEP 1 is  
553 the establishment of RBM plans as well as flood risk and drought risk management plans (Art  
554 3 WFD and Art 7 & 8 FD).

1. Clarify competencies of authorities directly or indirectly responsible for following an integrated approach to climate-resilient water management of river basins and establish an institutionalised process of cooperation (including transboundary) between them (Art 3 WFD, Art 3 FD) as well as across borders in a transboundary context.
2. Establish staff training and capacity-building programmes on climate change issues, e.g. to introduce water managers to climate change modelling, scenarios and projections and establish an ongoing institutionalised exchange of views with climate adaptation experts in other public bodies.
3. Enhance the effectiveness of water governance through capacity-building and collaboration across sectors.
4. Enhance communication and participation with stakeholders to raise public awareness about the need for more responsible water use, adaptation to climate change and to understand the relevance of safeguarding e-flows.

## 555 4.2 STEP 2: Assessing vulnerability to climate change in water management 556 planning

557 This is a crucial step that provides a comprehensive and detailed overview of current and future  
558 climate risks and related opportunities for water management based on the best available  
559 knowledge and different climatic scenarios, catering to uncertainties. This overview must  
560 include the expected risks to water resources, ecosystems, the ecological status as well as  
561 water-dependent community services and infrastructural assets. It is used to derive the climate  
562 change impact and vulnerability assessments (CCIV). However, these assessments normally  
563 do not go into detail when it comes to meeting the specific objectives set out in the EU  
564 legislation on water. Therefore, more detailed work at the RBD level might be needed and a  
565 comprehensive approach is crucial (See also Chapter 9).

566 Both the FD and the WFD have provisions to include such a CCIV assessment in the planning  
567 cycles (see section 5.1 for the WFD and section 6.1 for the FD). Climate risk assessments are

568 available at different geographical levels within the MS<sup>13</sup>. Such assessments are also  
569 fundamental for informing the prioritisation of water management and climate action.

570 Initially, it is imperative to conduct an extensive climate risk and vulnerability assessment,  
571 encompassing all potential climate hazards and evaluating their impacts across various sectors  
572 in order to promote planned adaptation. This assessment – which water managers should  
573 conduct in close cooperation with authorities establishing National Climate Adaptation  
574 Strategies and Regional Climate Adaptation Strategies – should move beyond standalone  
575 measures but should employ structural stimulation to address specific threats that cut across  
576 different sectors. The assessment process should not only adequately account for gradual  
577 changes in climate variables such as temperature and sea level, but also for more extreme  
578 weather and climatic conditions, and be founded on the most recent and reliable scientific  
579 information available. This will ensure that any decision-making process is based on a solid  
580 understanding of the potential impacts and risks.

581 The focus should not solely rely on historical hydrological data and trends. Instead, a range of  
582 climate projections and scenarios must be used to support the planning process. This approach  
583 allows proactive measures in handling future water fluctuations without posing increased risks  
584 to society, the economy, ecosystems, or downstream water users.

585 An essential aspect involves understanding the influence of climate change on other sectors  
586 directly associated with water management (see also section 5.5). This includes considerations  
587 such as the impact of climate change on water reuse plans in urban areas, shifts in drinking  
588 water production, and the implications for agriculture. It is important to extend the focus  
589 beyond the borders of individual rivers and look at the broader river basin level, considering  
590 transboundary implications and cooperation.

591 Identified uncertainties about the precise effects climate change has (in models, scenarios, and  
592 estimates), in most cases do not justify ‘doing nothing’ or continuing with ‘business as usual,’  
593 simply because these uncertainties are present in the baselines already. With the accumulating  
594 effects of climate change, the purported benefits of “wait and learn” appear much smaller than  
595 the expected costs of delaying action. The response to deep uncertainty should rather involve  
596 identifying “no regret” actions and flexible adaptive solutions as part of active preparations for  
597 more decisive action later. For the next RBM cycle(s), the major uncertainties should be  
598 properly reassessed when defining the baseline as well as designing and implementing policy  
599 measures, including mid-to-long-term adaptation to climate change strategies.

600 As uncertainty about climate impacts exists, careful management and communication become  
601 vital. Effectively communicating these uncertainties is essential for making informed decisions  
602 and building resilience and should therefore follow these key principles:

- 603 • **Transparency:** Communicate the sources and nature of uncertainties. This includes  
604 uncertainties in data, models, and assumptions used in the assessment.

---

<sup>13</sup> The latest information reported by MS can be found [here](#).

- 605 • **Probabilistic Information:** Express uncertainties in a probabilistic manner, using terms such  
606 as probabilities, confidence intervals, and likelihoods to convey the range of possible  
607 outcomes.
- 608 • **Scenario Analysis:** Acknowledge the diverse range of future scenarios and their associated  
609 uncertainties. Presenting a spectrum of scenarios allows decision-makers to consider a range  
610 of possible futures.

611

612 5. Take the latest and reliable scientific information provided by the [IPCC](#) and the [Copernicus Climate](#)  
613 [Change Service](#) into account for models and assessments to ensure that further actions and decisions  
614 are based on solid ground.

615 6. Prior to establishing RBM, FRMP and DRMP, water managers should consider the climate  
616 projections made in the national and regional climate adaptation plans and be aware of climate  
617 hazards relevant for water management. Assess possible risks in all sectors using water, including  
618 cascading impacts on these sectors (this assessment should go beyond stand-alone measures to  
619 address climate risks across sectors using regulations, benchmarking, and structural stimulation for  
620 one specific threat for one specific sector).

621 7. Do not only consider hydrological data and trends of the past in the risk assessment but also rely  
622 on a range of climate projections (due to uncertainty) and scenarios for improving RBM planning.  
623 Such a comprehensive approach allows to sufficiently address future water fluctuations, without  
624 creating increased risks for the ecosystem, and the downstream water uses.

625 8. Make sure to receive information related to the influence of climate change adaptation strategies on  
626 related sectors (energy, urban planning manufacturing, inland transport, etc.) and consider their  
627 coping-strategies which are directly related to water management.

628 9. Manage (e.g. perform sensitivity analysis or a scenario analysis) and communicate growing  
629 uncertainty carefully. By following a precautionary approach and communicating timely, the worst  
630 damage and losses can be avoided.

631 10. Work along adaptation pathways as a decision-focused approach (see next chapter 4.3).

### 632 4.3 STEP 3: Identifying adaptation options by considering different adaptation 633 pathways

634 In this step, the competent authorities identify relevant adaptation pathways that address both  
635 the consequences of climate change and other pressures identified and the related measures to  
636 adapt to climate change impacts.

637 Measures can be both structural and non-structural (e.g. social, behavioural, operational and  
638 institutional), such as reusing water, preserving wetlands and a blue carbon ecosystem,  
639 increasing the efficiency of water use, saving drinking water by reducing leakages, building  
640 dykes, and changing land use practices (IPCC, 2014). Public consultations under the WFD and  
641 FD can support the process of identifying these adaptation measures. The identification of  
642 adaptation pathways and related adaptation options should be aligned with the national and/or  
643 regional adaptation strategies in order to ensure policy coherence. Adaptation pathways may  
644 involve a combination of these strategies and therefore, integrating diverse adaptation options  
645 can enhance overall resilience to climate change. *Vice versa* the update of these strategies  
646 should take into account measures set out in RBMPs and FRMPs.

647 **Adaptation Pathways<sup>14</sup> can help** navigate this difficulty and inform the choice of robust  
648 adaptation steps. Overall, these pathways are understood as planned but flexible progressions  
649 of adaptation decisions, which function as a “road map” towards adaptation objectives wherein  
650 different sequential “turns” can be taken, depending on how the future unfolds (Haasnoot, et  
651 al., 2013). An adaptation pathways approach recognises that there are often many possible  
652 ways to respond to climate change and that a sequential, explorative combination of actions  
653 could present the best way to respond (Wise, et al., 2014). Adaptation pathways allow to  
654 identify hypothetical future timelines, taking into account changing conditions.

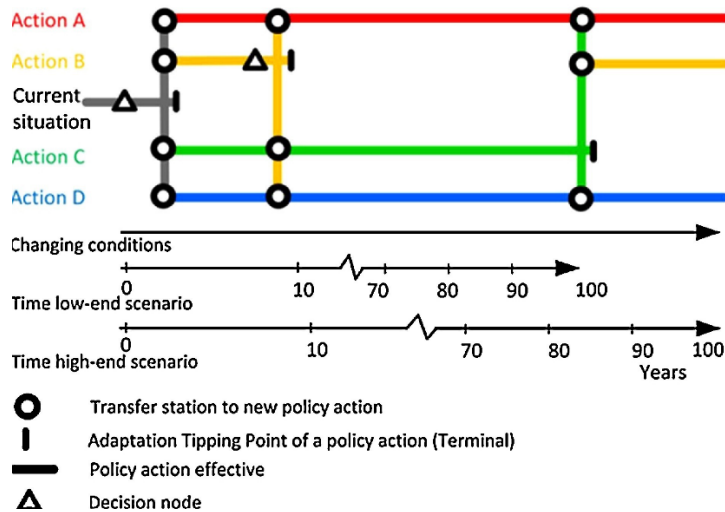
655 Furthermore, this method identifies how measures are connected to one another, e.g., which  
656 measure depends on others being implemented first, or which action rules out some future  
657 options. Thus, no- or low-regret actions can be identified, that maintain openness for other  
658 adaptation activities and needs in the future. Creating adaptation pathways is a complicated  
659 task that requires deliberation, inclusion, and expert assistance. Therefore, this section only  
660 provides an overview of different pathway approaches and introduces partners to turn to for  
661 designing pathways.

662 A large **variety of adaptation pathway methods** exist that differ in the context they are  
663 applied in, the clarity of the adaptation goal, certainty of responsibilities, and the overall  
664 methodological aim. They can be grouped into three clusters (Werners, Wise, Butler, Totin, &  
665 Vincent, 2021).

666 i. **Performance-threshold-oriented pathways methods:** These pathways start from the  
667 assumption that the current state of system functioning is satisfactory, e.g., the WFD or  
668 FD objectives are currently met. The goal is to maintain the system functioning under  
669 increasing climate impacts. When a parameter of system functioning drops below a  
670 certain quantifiable point, e.g., water depth to enable navigation, a measure is chosen  
671 within a defined temporal “window of action” to adapt. Thus, a pathway under different  
672 future scenarios can be drawn based on modelled environmental changes in an “if not  
673 A, then B or C” fashion. These pathways function in a data-rich context, where the goals  
674 are agreed upon and the responsibilities now and in the future are clear.

---

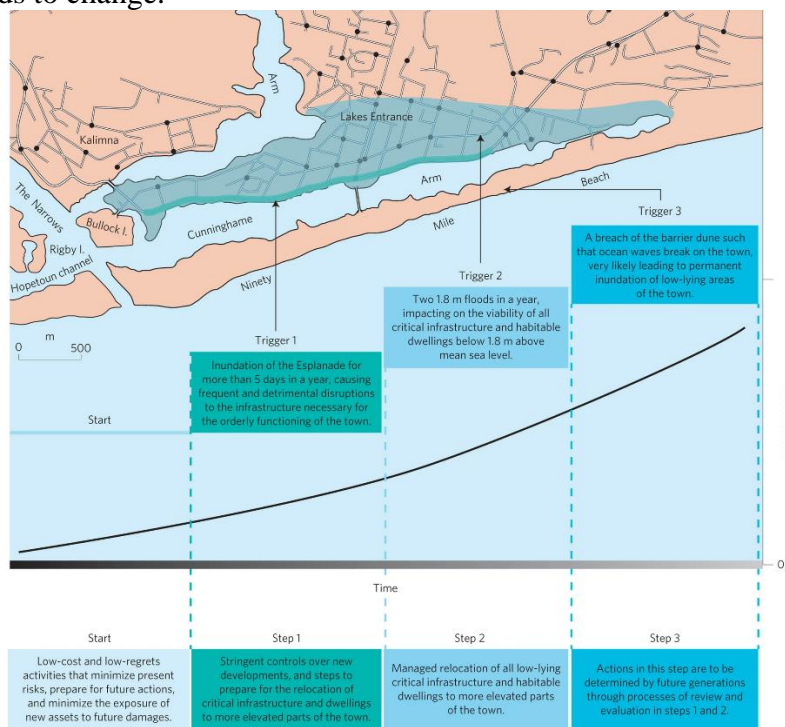
<sup>14</sup> A series of adaptation choices involving trade-offs between short-term and long-term goals and values. These are processes of deliberation to identify solutions that are meaningful to people in the context of their daily lives and to avoid potential maladaptation (IPCC, 2022a).



675

676 *Figure 4: A schematic depiction of a Performance-Threshold Pathway as used in the Dutch Delta Programme*  
 677 *(Deltares, 2023). The timeline runs from left to right, under different change scenarios. Lines are different*  
 678 *implemented effective actions. Circles show points to make a new policy decision, and dead ends show the end*  
 679 *of a window of action, after which a measure is no longer effective for adaptation.*

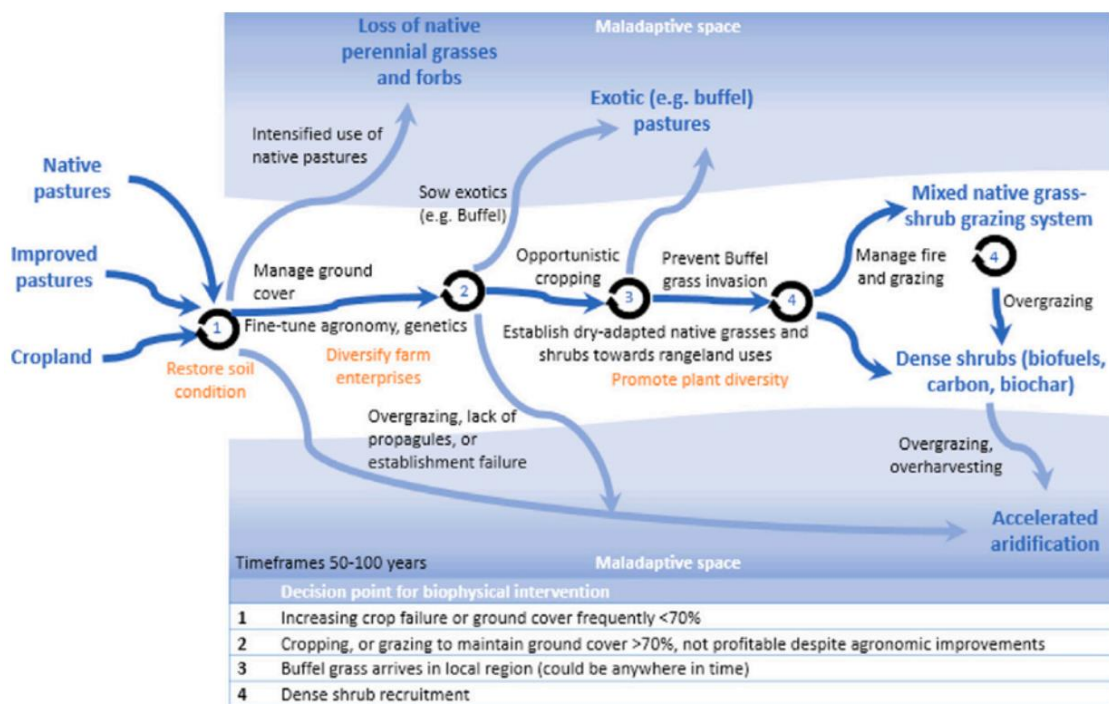
680 ii. **Multi-stakeholder-oriented pathways methods:** This cluster focuses very much on  
 681 the process of pathway development, which is under the inclusion of different  
 682 stakeholders. Thresholds are not defined as environmental parameters but rather as  
 683 changes that are relevant to the people. This is done to increase acceptability, build the  
 684 adaptive capacity of the community by involving them in planning processes, and to  
 685 harvest local knowledge on e.g., what happens exactly when a specific area floods and  
 686 what needs to change.



687

688 *Figure 5: An example of a Multi-Stakeholder Pathway on coastal adaptation to rising sea levels*  
 689 *(Barnett, et al., 2014). The timeline runs from left to right, and different stakeholder-defined triggers mark when certain steps*  
 690 *have to be taken, leaving room for future generations to identify the best steps in their time.*

691 iii. **Transformation-oriented pathways methods:** In contrast to the other clusters, these  
 692 pathways start from the recognition that deeper change is necessary to successfully adapt  
 693 in the long-term. This deeper change could comprise trying to tackle the root of  
 694 adaptation issues and changing framework conditions such as institutional arrangements  
 695 and decision-making processes. Transformation pathways do not start from the present  
 696 and identify points where adaptation is needed, but rather define a future goal that may  
 697 differ significantly from the present on many levels, and back-cast the necessary steps  
 698 towards the present. Thus, short-term, and long-term actions can be identified.



699

700 *Figure 6: An example of a Transformational Adaptation Pathway for restoring a native ecosystem on Farmland*  
 701 *(Prober, et al., 2017). The timeline runs from left to right, deep blue are desirable outcomes and light blue*  
 702 *maladaptive outcomes drifting into the maladaptive space. Circles are decision points when action has to be*  
 703 *taken, the orange text identifies actions to increase resilience.*

704 Aspects of these three clusters can be combined to fit a local context and form an idea of how  
 705 to reach adaptation goals. If correctly applied, pathways provide transparency and planning  
 706 security to stakeholders, which enables stakeholders to take necessary adaptation actions  
 707 themselves and encourages continuity of investment over longer periods of time. Furthermore,  
 708 a variety of strategies and actions are considered, which allows choosing the most cost-  
 709 effective adaptation paths (Marks, Liu, & Krans, 2021).

710 The OECD has developed an analytical framework that can support the design of strategic  
 711 investment pathways. It can serve as a source of inspiration and a basis for discussion on the  
 712 strategic planning of water-related investments in MS (OECD, 2022b).

- 713 11. Align water planning instruments closely to national and regional climate adaptation strategies.  
 714 12. Work along adaptation pathways as a decision-focused approach. An adaptation pathways approach  
 715 recognises that there are often many possible ways to respond to climate change and that a  
 716 combination of actions, some of which are taken now and some that may be taken in the future,  
 717 could present the best way to respond.

- 718 13. Prefer adaptation options which are robust in various sets of climate change and land use scenarios  
 719 as well as adaptation pathways and do not commit too firmly to one particular projection of the  
 720 future by building flexibility into your water management and land use systems.
- 721 14. Prioritise equitable access, efficient water use, and maintain e-flows to scarce water resources in  
 722 new strategies within a river basin, recognising the unequal distribution of climate change impacts  
 723 and disparities of adaptation capabilities.

724

#### 725 4.4 STEP 4 Assessing adaptation options

726 This step comprises the assessment and ranking of the identified water management/adaptation  
 727 options. Such an assessment must include criteria of criteria effectiveness, feasibility and costs  
 728 to reach the specific objectives set out by the WFD and FD<sup>15</sup> but also aspects like climate  
 729 proofing and just resilience<sup>16</sup>.

730 Climate proofing refers to the process of assessing and modifying policies, plans, programmes,  
 731 and measures to make them more resilient to the impacts of climate change but still reaching  
 732 the water management objectives (e.g. good status). The goal is to ensure that these measures  
 733 are robust and effective in terms of changing climatic conditions and to avoid maladaptation.  
 734 A detailed approach of how to perform climate-proofing is found in Chapter 10.

735 **Maladaptation** includes adaptation actions that have negative side-effects or outcomes,  
 736 directly or indirectly, at a later point in time or in other areas, sectors, or parts of society. Such  
 737 consequences are usually unintended. Maladaptation may compromise the ability of a water  
 738 body to meet GES/P because an action inadvertently changes the physico-chemical or  
 739 hydromorphological elements in a water body, for example by modifying upstream or  
 740 downstream flow conditions. Focusing on a single scenario instead of exploring a range of  
 741 possible future climates can result in under-design (and a risk of a stranded asset) or over-  
 742 design (with unnecessarily high costs): flexible and adaptive designs are less likely to result in  
 743 maladaptation. Some actions may result in increased CO<sub>2</sub> emissions. Others may not take into  
 744 account longer-term consequences.

745 Maladaptation is formalised in the EU by the ‘[Do No Significant Harm](#)’ (DNSH) principle.  
 746 The principle is relatively new and applies to private and public finance. The aim is that MSs  
 747 improve their capacity to apply the DNSH principle to public investments from EU and  
 748 national funds and programmes, including from the Recovery and Resilience Facility (RRF).  
 749 MSs need to provide a DNSH assessment for each and every measure (i.e. each reform and  
 750 each investment) of their Recovery and Resilience Plan (Article 14 of the RRF Regulation),  
 751 including water management measures.

752 **Just Resilience** aims at reducing the unequal burden of climate risks and ensuring equity in  
 753 the distribution of benefits (and burdens) of adaptation (e.g. Recognising and addressing

---

<sup>15</sup> See also [WATECO](#) (2003)

<sup>16</sup> The concept of ‘leaving no one behind’ is a key element in recent and forthcoming EU policies related to climate adaptation, including the European Green Deal policy package and the EU Mission on adaptation to climate change.

754 gender-specific vulnerabilities and capacities in adaptation planning). Article 9 in combination  
 755 with Annex III of the WFD allows to consider social aspects in the development or definition  
 756 of water pricing policies. Just Resilience aspects should also be considered in the development  
 757 of Flood Risk Management and Drought Risk Management Plans.

758 Meaningful engagement of vulnerable groups in these processes is also essential. When doing  
 759 a cost-benefit analysis of flood risk reduction measures, the consideration of social welfare  
 760 including individual social vulnerability<sup>17</sup> through relative impacts on consumption is  
 761 important to reduce vulnerabilities for the poorest (Kind, Botzen, & Aerts, 2020).

*Example 2: Social Vulnerability Assessment for Flood Risk Analysis*

In the municipality of Ponferrada in Spain a methodology for analysing social vulnerability to floods was developed by integrating and weighting exposure and resistance indicators. The indicators include population density, evacuation time, emergency service personnel ratios, health staff, and qualitative measures. To weigh each of those indicators, an Analytic Hierarchy Process was conducted and experts from various fields were involved. The results provide a detailed social vulnerability map on an urban plot level, aiding flood risk planning and management in terms of selecting and placing measures. In order to allow replicability of the methodology, the majority of data used for the calculation of the indicators comes from open public data sources (Tascón-González, et al., 2020).

762

15. Make sure that water management adaptation measures and plans are climate-proofed, besides ensuring that they contribute to reaching the set objectives. When choosing between alternative climate adaptation options for water management, preference should go to solutions that prevail above others in alternative climate evolution scenarios.

16. Ensure that resilience-building efforts are fair and just, providing equal opportunities and resources for all communities, particularly marginalised or vulnerable groups.

#### 763 4.5 STEP 5 Implementation

764 The fifth step consists of putting into effect the preferred climate adaptation options in the  
 765 context of the RBMPs, FRMPs or DRMPs. There is a broad portfolio of instruments available  
 766 that can be used to implement adaptation measures (Climate ADAPT, 2023a):

- 767 i. Legal instruments (laws, regulations, decrees, ‘soft law’ such as standards)
- 768 ii. Economic instruments (funding, taxes, fees, public procurement, grants, loans, market-based)
- 769 iii. Informational instruments (studies, databases, information campaigns, advice, supervision,  
 770 training of staff, guidance and work aids, disaster education to raise awareness of community  
 771 people, events, websites)
- 772 iv. Partnership instruments (Public Private Partnership Agreements, voluntary agreements,  
 773 collaborative projects)
- 774 v. Hybrid strategic/planning instruments (plans, strategies, programmes, planning instruments)

---

<sup>17</sup> Social vulnerability is distinguished between immediate vulnerability addressed through short-term interventions (e.g. emergency response measures during and after a disaster) and a form of vulnerability, which changes over time due to factors such as economic development, changes in infrastructure, social policies, and community resilience-building efforts.

775 Implementation of adaptation measures for the water sector might also require action beyond  
 776 the water management sector. Therefore, it is essential that mainstreaming water adaptation  
 777 planning occurs at all levels of sectoral policy-making including, e.g. defining the policy  
 778 agenda and designing legislations, strategies, and instruments (such as programmes and plans).  
 779 The coherence of different policies with common water-oriented goals is essential to minimise  
 780 conflicts, avoid trade-offs and foster mutual synergies. For example, if a new infrastructure  
 781 project might have significant impacts [e.g. directly on the hydro morphology or indirect via  
 782 changing soil conditions (e.g. soil sealing<sup>18</sup>) on local water bodies], it is important that water-  
 783 relevant aspects are included from the beginning of the planning process. Considering water  
 784 resilience already from the initial phases of a project not only prevents expensive adaptation  
 785 measures from being implemented afterwards but also leads to positive linkage effects (e.g.  
 786 water-related ecosystems provide benefits in terms of climate mitigation and reduce disaster  
 787 risk from flooding) (Climate ADAPT, 2023a).

*Example 3: VigiEau: An innovative solution to communicate on drought in France.*

The [VigiEau](#) website was launched in 2023 by the French Government to support the implementation of its drought risk planning and to support citizens' and businesses' understanding of and provide information on drought restrictions. Homeowners should thereby be encouraged to reduce their water usage in order to limit the impact of droughts and to avoid fines. It provides a colour-coded map of France showing the different communes and departments where water usage restrictions are currently applied. The restrictions are split into five categories: Watering gardens and green spaces; Filling swimming pools and playing water-based games (e.g. water slides); Cleaning your home and car; Using water for a fountain; Impact on building works. Citizens can research by entering their home address, which of these categories are currently in place in their area. VigiEau allows the French government to render the type of drought management measures taken more transparently and consistently at the regional level while leaving implementation decentralised.

788

*Example 4: The Blue Deal in Flanders*

Facing water scarcity and drought risks, Flanders has launched the [Blue Deal](#) programme to address these challenges. The Blue Deal addresses some specific vulnerabilities of Belgium, among them the inability of soil to absorb precipitation due to land sealing, and one of Europe's highest water exploitation per capita. 13 projects with a total budget of 343 million Euros invested by the regional Government of Flanders have been launched. The goal is to increase the water availability to restore the sponge function of wetlands, create storage for alternative water resources, reduce leakage losses and support innovative projects. Furthermore, the water demand should be reduced by using water more efficiently in order to retain water longer upstream and raise the amount of available water. A task force led by the Flemish Minister of Environment oversees the progress, ensuring effective implementation, and the participation of stakeholders, including companies, farmers, citizens, and governmental bodies.

789

*Example 5: Incentivise a proactive attitude on resilience.*

[ARERA](#) – the national economic regulatory authority in charge of the water and sanitation sector in Italy – has recently introduced a specific mechanism aimed at improving resilience in its regulatory mechanism dedicated to enhancing the quality of water resources, environment and provide service.

---

<sup>18</sup> See also the [Soil Strategy](#).

The Italian technical quality mechanism is based on a number of KPIs, so-called, macro-indicators, addressing the main targets in terms of preserving water resources when providing the service:

- i. water losses;
- ii. service interruptions;
- iii. water quality for users or preserving the environment;
- iv. adequacy of sewage systems;
- v. water treatment sludges;
- vi. quality of treated wastewater

Macro-indicators have been chosen with strict output-based criteria and with a particular attention to the principle of technological neutrality. ARERA quality regulation fixes targets for each operator depending on its specific starting situation (higher targets for operators more distant from an optimal situation) and associates an award/penalty mechanism, according to the fact that targets have been reached (or not, in which case the operator gets a penalty) for each macro-indicator. In the first 4-years of implementation, the Italian regulator has provided awards for an overall 265 million Euros and penalties for 24 million Euros.

790 Lack of financing is often an issue in the implementation of measures and plans. Under the EU  
791 mission for climate change adaptation an overview of EU and national funding sources is  
792 provided.

- 793 17. Align RBM plans to climate change adaptation strategies and involve/inform relevant stakeholders.  
794 Ensure that water managers are aware of other sectoral climate adaptation efforts to consider them  
795 at an early stage.
- 796 18. Involve diverse stakeholders, including local communities, marginalised groups, and indigenous  
797 peoples, in decision-making processes related to resilience planning and implementation. Their  
798 awareness and cooperation are crucial in the practical reality.
- 799 19. Building on the risk assessment, climate adaptation should be mainstreamed into all decision-  
800 making and policy processes relevant for integrated water management, with the policies listed as  
801 informing the basic measures in the PoM for a RBMP at its core (WFD, Art 11).

802

#### 803 4.6 STEP 6: Monitoring & Evaluation

804 The final step involves continuous monitoring and evaluation of the effectiveness of the plan  
805 over time. This includes tracking the implementation progress, assessing the outcomes and  
806 impacts of the adaptation measures, and regularly adjusting the plan as needed based on the  
807 results of the evaluation. Both, the WFD under Annex V (1.3. and 2.2) and Art 13(4) in  
808 connection with Annex VII(B) and the FD under Art 7 in connection with Annex A(B) provide  
809 provisions for monitoring schemes which could be integrated into such a monitoring and  
810 evaluation concept.

811 In conclusion, while the WFD and the FD precede the Commission's [Guidelines](#) on National  
812 Adaptation Strategies, they already foresee administrative steps which are directly relevant to  
813 climate adaptation. Importantly, as set out above, water planning instruments must be closely  
814 aligned to national climate adaptation strategies. Water managers are well advised to consider  
815 competing climate change scenarios to account for uncertainty as recommended in their  
816 respective national climate adaptation strategy.

- 817 20. Monitor and evaluate the processes of mainstreaming that help policymakers determine if the  
 818 desired outcomes are achieved. Evaluating also enables the timely adjustment of policies if needed.  
 819 21. Monitor the impact of measures taken to address the impact of climate change on water  
 820 management in order to enable the improvement of measures over time.  
 821 22. Build the monitoring and evaluation scheme on existing provisions set out in the WFD (Art 8.) and  
 822 FD (Annex A II 1).

823

## 824 5 WATER FRAMEWORK DIRECTIVE AND ADAPTATION

825 The WFD was adopted eight years after the UN Framework Convention to Combat Climate  
 826 Change (UNFCCC, 1992), thus the acute need to reduce GHG as well as the impacts of climate  
 827 change were already well known. Article 1 of this Directive indicates that its purpose is to  
 828 protect and, where necessary, restore water bodies to reach good ecological and chemical  
 829 status, and to prevent a deterioration in status, while *inter alia* establishing a framework to  
 830 contribute to mitigate the effects of droughts and floods. The underpinning rationale and  
 831 process of the WFD are amenable to contributing to adaptation. In particular, the integrated  
 832 approaches to land, water and ecosystem management, combined with the cyclical review of  
 833 progress, are all consistent with adaptive management. Focusing on the resilience of healthy  
 834 aquatic ecosystems to changing and degrading conditions, for instance, provides a cost-  
 835 effective and relatively easy way to achieve adaptation.

836 It should be kept in mind that climate change impacts in one part of a river basin can have  
 837 implications for the achievement of WFD objectives in other parts. Therefore, regional and  
 838 (where applicable) international cooperation plays an important role. Please check the  
 839 recommendations in Chapter 9 on the need to develop joint and coordinated adaptation  
 840 strategies in RBMP of international RBDs and coordinate cooperation for marine waters, where  
 841 the connectivity of river basins with coastal and marine waters requires national and  
 842 international adaptation strategies.

843 Some of the RBM steps are considered more critical than others with respect to the ability to  
 844 prepare for climate change, especially in the short term. Essential components for planning are:

- 845 i. Ability to identify emerging change through monitoring and modelling to adapt the  
 846 necessary assessment of characteristics, types, reference conditions and status of  
 847 water bodies,
- 848 ii. Ensuring that the scale of climate change impacts and projected future anthropogenic  
 849 pressures and risks is understood.
- 850 iii. Developing and prioritising multiple-benefit catchment-based solutions which  
 851 restore or maintain the natural characteristics of catchments to build resilience to a  
 852 range of possible climate futures.
- 853 iv. Secure funding and capacities for the implementation of plans

854 These parts of RBM should be the focus of MSs when considering how to deal with climate  
 855 change.

## 856 5.1 Pressure and impact assessment

857 MSs are required, under Article 5 of the WFD, to review all pressures on water bodies,  
858 including the impact of human activity, (e.g. point and diffuse source of pollution,  
859 abstractions), on the status of surface waters and groundwater (see Annex II of WFD for  
860 technical specifications), but also pressures resulting from climate change. The considerations  
861 outlined below relate to climate change induced pressures and impacts.

862 Most of the WFD pressures are sensitive to climate change, whose main impacts are  
863 summarised in Chapter 2. The direct effects of climate change, such as increased air and water  
864 temperatures and higher frequencies of extreme meteorological events, can interact with human  
865 responses to climate change, known as ‘indirect effects’. These ‘indirect effects’ can sometimes  
866 have a greater impact than the direct effects of climate change.<sup>19</sup>

### 867 5.1.1 Surface Water

868 Evaluate how climate change affects surface water bodies. Consider Climate change effects  
869 such as increased water temperatures, altered precipitation patterns (amount, intensity,  
870 frequency and type), extreme weather events, and rising sea levels have a direct impact on  
871 surface water bodies. In many cases, the effect depends on the development of different sectors  
872 putting pressure on the water bodies. These changes can impact water quality, quantity, and  
873 ecosystem health (See also Chapter 2). The following steps may be useful:

- 874 i. **Identification and assessment of impacts** on water bodies: Estimate  
875 identify/assess/model the combined impact of climate change in and the  
876 development of different anthropogenic pressures on the ecological status or  
877 potential and chemical status of surface water bodies as well as on the quantitative  
878 and chemical status of groundwater bodies.
- 879 ii. **Assessing pressures and impacts:** Various potential climate change scenarios  
880 should be considered in the assessment of pressures and adaptation measures  
881 covering the entire river basin across borders. It may be supportive to develop  
882 models that project the potential future state of water bodies under various climate  
883 change conditions and sectoral developments<sup>20</sup>. This could involve scenarios like  
884 increased drought, heavier rainfall, altered flow patterns, and changing temperature  
885 regimes combined with the projected development of different sectors. It is  
886 recommended that you liaise with your national meteorological services to identify  
887 those climate projections that you should use for your assessment.
- 888 iii. In designing adaptation strategies, align strategies with the projections in national  
889 adaptation strategies or plans based on pathway approaches at the regional and local  
890 levels (see section 4.3). This could involve modifying water management practices,

---

<sup>19</sup> For example, changes in land-use practices in response to climate change, such as adjusted cropping regimes or a shift to renewable hydroelectricity to mitigate climate change, can very strongly affect freshwater ecosystems (Brosse, et al., 2022).

<sup>20</sup> In this context it is also important to evaluate the dynamic relationships between surface water and groundwater together with the ecosystems connected to them.

891 developing NBS to handle extreme events, restoring habitats, changing agricultural  
 892 practices and ensuring e-flows.  
 893

*Example 6: Nutrient Emissions Modeling supporting climate resilient Danube River Basin Management*

In drafting the updated Danube RBMP (DRBMP 2021), coordinated by the International Commission for the Protection of the Danube River (ICPDR), an approach was taken to tackle climate change impacts on water quality. The DRBMP 2021 focuses on five significant water management issues, which are the main pressures that affect the water status, including the effects of drought, water scarcity, extreme hydrological phenomena, and other impacts. The use of the MONERIS model at the basin-wide level enabled an estimation of nutrient emissions, identifying sources and pathways contributing to the total emissions.

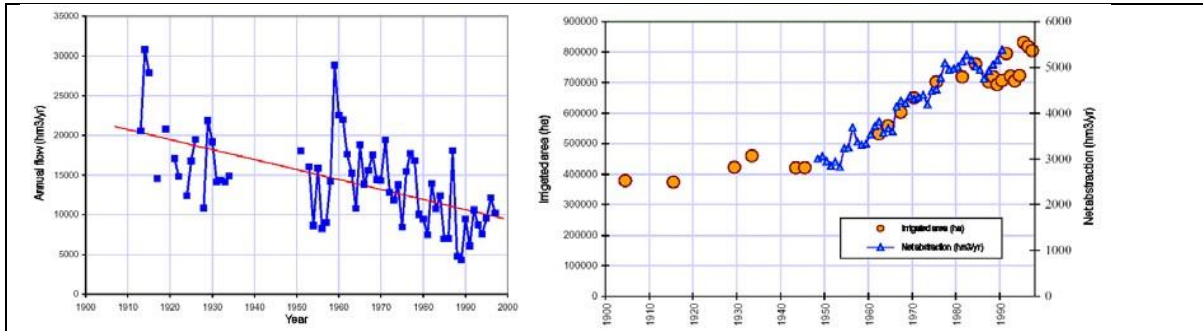
The model, applied at the sub-catchment scale, assessed nutrient emissions under extreme "dry" and "wet" conditions, incorporating climate change scenarios and measure implementation. The results for Romania showed that for low water conditions (dry situation), lower nutrient emissions are expected, forecasting a 7.5% (N) and 10% (P) emission reduction of the total nutrient emissions compared to the vision scenario. On the other hand, in peak runoff years (high waters), runoff and potentially soil erosion are more important, leading to increased diffuse emissions. Thus, in the case of maximum discharge conditions (wet conditions), an increase compared to the vision scenario of emissions by 23% (N) and 20.2% (P) of the total nutrient emissions is expected.

894  
 895 Observed hydrogeological changes should be formally linked to climate change in a  
 896 standardised manner to enable Europe-wide comparisons. Guidance should be developed for  
 897 implementation across all water body types and should take into account the issues outlined  
 898 above. An example of such guidance is the development of calibrated assessments of observed  
 899 weather and climate-related events and the identification of any changed risk of such events  
 900 attributable to climate factors (WMO, 2011).

901 An example from the Ebro River in Tortosa, Spain, highlights the need to provide  
 902 comprehensive guidance and common standards to facilitate the robust attribution of observed  
 903 hydrological impacts in a way that enables an assessment, reporting, and comparison between  
 904 catchments, regions, and countries.

*Example 7: Trend detection in the lower Ebro River*

The subject of natural flows in the lower Ebro has been one of intense controversy throughout the years. The observed flows at the most downstream station of the Ebro River in Tortosa (figure on the left) show a decreasing trend which has been attributed to climate change. However, the analysis of a series of natural flows obtained through rainfall-runoff modelling, combined with the observed record at Tortosa and the storage fluctuations in the reservoirs allows an estimation of water consumption in the basin, which correlates quite well with the historic development of irrigated areas in the basin as shown in the figure on the right. Only a very dense monitoring network would be able to assess whether a decreasing trend of natural flows in the Ebro River is occurring.



905

906 

### 5.1.2 Groundwater

907 In terms of a risk assessment, it is necessary to carefully analyse the temporal development of  
 908 the renewed groundwater volume which is highly dependent on the effects of climate change  
 909 on precipitation, temperature, evapotranspiration, changing snow and ice regimes, etc. and land  
 910 use/land cover regulating the groundwater recharge conditions. This is typically achieved by  
 911 assessing groundwater quantitative trends through precipitation, piezometric and  
 912 evapotranspiration measurements either at national or catchment scales. An essential parameter  
 913 in the assessment of the sustainable use of groundwater, and thus the risk assessment, is the  
 914 available groundwater resource, which includes both groundwater recharge and the  
 915 groundwater needs of aquatic and terrestrial ecosystems that depend on groundwater.

916 For monitoring programmes to identify climate-driven impacts on groundwater quantity,  
 917 changes must first be detected/observed, and they must then be assessed as to whether they  
 918 were caused by climate change or some other influence. The process of determining whether  
 919 changes have been caused by climate change is called “attribution” and has been defined by  
 920 the IPCC as ‘the question of the magnitude of the contribution of climate change to a change  
 921 in a system’ (Cramer, et al., 2014; IPCC, 2014). There are large uncertainties in attributing  
 922 trends in groundwater quantity to climate change robustly (IPCC, 2014), mainly due to  
 923 limitations in the spatio-temporal coverage of groundwater monitoring networks, abstraction  
 924 data and numerical representations of groundwater recharge processes. Attribution of observed  
 925 trends to climate change is often a tedious task which needs to be approached in a systematic  
 926 manner. High quality and appropriate meteorological and groundwater data is required to  
 927 facilitate unambiguous attribution, as well as a clear understanding of the processes by which  
 928 meteorological changes can impact groundwater quantity. Such processes may be non-linear,  
 929 be subject to impact thresholds or be spatially and/or temporally heterogeneous, e.g. long lag-  
 930 times.

931 Groundwater monitoring and assessment is primarily concerned with attribution of long-term  
 932 annual and seasonal trends. However, **no EU MS appears to have in place a formal,  
 933 standardised, and specific process for attributing observed groundwater quantitative and  
 934 qualitative changes or their impacts to climate change.**

935 The identification of groundwater bodies that are either vulnerable or resilient to climate  
 936 change impacts is another important element of adaptation planning. Approaches classifying  
 937 groundwater bodies typically use a modelling approach and a combination of meteorological  
 938 and hydrogeological criteria. The temporal dimension is an important aspect that needs to be

939 considered when assessing vulnerability, as some groundwater bodies with low storability and  
 940 direct recharge may be vulnerable to short-sharp droughts, while other more buffered  
 941 groundwater bodies may be more vulnerable to multi-year or long-term droughts. Some  
 942 groundwater bodies are multi-aquifer formations which should be considered in the  
 943 vulnerability assessment and coastal aquifers are very often vulnerable to both, the decrease in  
 944 recharge, the increase in pressures and the resulting chemical degradation due to saline  
 945 intrusion.

23. Put in place a formal, standardised, and specific process for attributing observed water quantitative and qualitative changes to the impacts of climate change. In so doing, assess the change of drivers and pressures on groundwater bodies due to climate change over a range of timescales, considering along with direct and indirect drivers of water scarcity influences but also consider adapting activities to climate change.
24. Consider climate change in the economic analysis according to Article 5 WFD (and Annex III) in the context of recovering the cost of water services (WFD Article 9) and for defining measures in the programme of measures. To perform a proper climate water risk assessment as part of the pressures and impact assessment and the economic analysis, consider the long-term water supply and water demand forecasts and scenario, and subsequently, the Costs-Effectiveness-Analysis underpinning the set of measures in the PoM and the investment planning/forecasts.

946

## 947 5.2 Status Assessment

### 948 5.2.1 Surface water body typology, reference conditions and classification

949 The implementation of the WFD is based on objective and transparent criteria and procedures  
 950 as agreed in the CIS, e.g. for defining surface water body types, reference conditions, and  
 951 quality class boundaries. Furthermore, it is based on robust monitoring data. Although climate  
 952 change has the potential to impact all quality elements included in the definition of ecological  
 953 status (biological, physio-chemical, hydromorphological), this does not affect the principles of  
 954 water status assessment, which remains valid. However, we must ensure that the WFD  
 955 approach remains valid and even optimised to protect aquatic ecosystems for the coming  
 956 decades alongside pervasive climatic change.

957 According to the WFD, the overall surface water status is determined by the QE in the poorest  
 958 status of its ecological status/potential and chemical status. Biological Quality Elements (i.e.,  
 959 fish, invertebrates, phytoplankton, etc.) are the key components in the classification of surface  
 960 water bodies and they indicate the impact of multiple pressures. This very sensitivity of the  
 961 biological species to changes in their environment makes the WFD classification system  
 962 susceptible to the impact of climate change. The challenge is therefore adapting the approach  
 963 to status assessment in the context of climate change while maintaining focus on implementing  
 964 measures to tackle key pressures such as nutrients, other pollutants and hydromorphological  
 965 alterations to achieve environmental objectives. The fundamental drivers of changes are  
 966 temperature, hydrology, and sea level rise. Some key thematic impacts on aquatic systems  
 967 include altered morphology, hydrology including floods, droughts and disrupted seasonality of  
 968 flow as well as altered nutrient export, delivery and mineral cycling. Also important is **the**  
 969 **threat of increased salinisation from droughts and saline intrusion**. In addition, the

970 changing in the timing of the seasons can lead to a phenological mismatch, for example  
 971 between prey and predators with implications across the food chain or changes in community  
 972 composition. Changes in environmental conditions could also enhance **the settlement of**  
 973 **invasive species** and affect the structure of the indigenous community and native biodiversity.

974 Surface water bodies are characterised into water body types by a set of obligatory factors and  
 975 descriptors for both systems A and B in Annex 2 to the WFD (e.g., topographic, geological,  
 976 physical, hydrological). System B has the option of using additional natural factors (e.g., water  
 977 depth, mixing characteristics, background nutrient status). A number of these factors are  
 978 climate-sensitive. Water bodies could therefore migrate from one type to another because of  
 979 gradual climate change or a sequence of extreme events (Nõges, 2009).

980 **If the type of some water bodies will permanently change as a result of climate change**  
 981 **despite all additional measures implemented, these water bodies should be assigned to an**  
 982 **appropriate type within the existing typology and the corresponding reference conditions**  
 983 **applied to them.** If there is no possibility for re-assignment to an existing type, a new type  
 984 could be created or the existing type updated with its specific reference conditions and class  
 985 boundaries. However, in this case, it is important to verify whether the new or updated class  
 986 boundaries need to be intercalibrated. Modelling can also be used to predict likely changes,  
 987 examining similar types at warmer latitudes for example.

988 According to Article 5(2) WFD, the review of the characterisation of water bodies should take  
 989 place every six years. In some cases, it may be necessary to refine the definition of types, as  
 990 indicated in System B (e.g. using more climate-sensitive parameters like channel morphology,  
 991 air temperature, and precipitation) in order to define additional types. See Table 2 for a list of  
 992 typology parameters listed in either system A or B (Solheim, et al., 2019) along with estimated  
 993 sensitivity to climate change. However, before changing the typology and associated reference  
 994 conditions, all other options and measures should have been exhausted in order to avoid  
 995 lowering the ambitions of the environmental objectives.

996 One example of such changes is the increasing background loading influx of humic substances  
 997 to northern rivers and lakes (the so-called browning), which may cause them to change from  
 998 clearwater types to humic types. However, increased browning can also result from catchment  
 999 land use change altering ecosystem functioning representing a challenge to partition global,  
 1000 local and regional drivers into what might be defined as typological or pressure-driven change  
 1001 (Asmala, et al., 2019), which should lead to the implementation of suitable measures and not a  
 1002 change in typology. Changes in typology can be more prevalent in specific environments, for  
 1003 example, alteration of natural turbidity is particularly important for water bodies with clay  
 1004 deposits or glacial silt. Ecosystems of some types of water bodies, e.g. large shallow lakes and  
 1005 rivers in arid regions, are more physically controlled and thus more sensitive to climate change.  
 1006 More information on this example and other examples related to changes in the natural  
 1007 conditions of water bodies are introduced in ANNEX II.

Typology factors	Rivers	Lakes	Transitional	Coastal	Relevance for climate change
Size		+			
Mean depth		+	+		

Altitude					
Region					
Geology: Alkalinity	+	+			
Geology: humic substances (colour)	+++	+++	++	+	Northern Europe mainly
Flow	+++		+		
Residence time		+++	++		
Mixing		+++	++	++	
Temperature	+++	+++	+++	++	
Background nutrient status	+	+	+		
Salinity/chloride/conductivity	++	++	+		
Substrate composition	+++	++	++	++	
Water level fluctuation		+++			
River width	+++				
Morphology/shape	+++	++	+		
Solids/turbidity (natural)	+++	++	+		Clay deposits/ glacial silt
Precipitation	+++	++			
Tidal range	+		+		
Wave exposure		+	++	+++	

1008 *Table 2: Main typological factors in use for lakes, rivers, and coastal/transitional waters (System A & B typology factors) and*  
1009 *their sensitivity to climate change*

1010 For water bodies negatively affected by climate change, more intensive monitoring should be  
1011 implemented to better understand the pace and mechanisms of such a change, in order to  
1012 ascertain also whether such changes gradually modify the natural conditions of the water body  
1013 such that a re-allocation to a new water category or type becomes appropriate.

1014 In fact, a robust long-term monitoring network of reference sites, i.e. with no or very limited  
1015 anthropogenic impact, with sufficiently long series of data would be the most direct way of  
1016 detecting responses of water bodies to climate change impacts. In practice, MS use slightly  
1017 different criteria for selecting reference sites. The use of the best available sites instead of real  
1018 reference sites should be marked as such and defined as an alternative benchmark (e.g. good  
1019 status) (see [Guidance document No 10, 2003](#)). If the conditions at reference sites change, it  
1020 would be important to find out the causes and decide whether the site can still be used or not  
1021 as a reference site.

1022 Many biological systems are already showing thermally and hydrologically induced changes,  
1023 although disentanglement from other anthropogenic pressures can be difficult. Therefore,  
1024 climate change signals may confound the analysis of trends expected from PoM implemented  
1025 in WFD RBM cycles.

1026 It is important to account for inter-annual and decadal natural climate variability, often  
 1027 identifiable by examining teleconnection indices such as the North Atlantic Oscillation (NAO)  
 1028 and the Atlantic Multidecadal Oscillation (AMO). Therefore, status definitions should be  
 1029 sufficiently long to accommodate natural variations within types. Given the short duration of  
 1030 many monitoring programmes, short-term tendencies in ecological status should be interpreted  
 1031 with great caution, although climate-driven dramatic shifts are also possible (e.g. from droughts  
 1032 or floods). Other data on biological composition or supporting elements may prove to be useful  
 1033 in extending the time series to examine change.

1034 If the intensified monitoring is giving scientific evidence of climate change having a direct  
 1035 negative impact on one or more quality elements, additional measures shall be taken to achieve  
 1036 original objectives. If despite additional measures, climate change is causing irreversible  
 1037 changes in the natural conditions, the water body could necessitate re-allocation to another  
 1038 existing type as mentioned above.

1039 Anytime there is a significant risk that climate change may compromise the achievement of the  
 1040 WFD objectives, this should be noted in the RBMP and communication with stakeholders and  
 1041 the general public should take place since it is relevant information to river basin managers and  
 1042 may assist in considerations of optimisation of scarce resource use between locations and  
 1043 objectives.

25. Include reference sites in surveillance monitoring programmes to understand the extent and causes of natural variability and the impact of climate change (see point 1.3.1. Annex V to the WFD).
26. Distinguish between Climate Change pressures and other anthropogenic pressures for the purposes of effective management, maintain long-term, high-resolution, homogeneous and quality-controlled meteorological, hydrological, water quality and biological monitoring systems. Sites having a long history of monitoring should be prioritised.
27. Consider using re-analysis – a blend of measured and modelled data to produce a complete data record – for example use the data available at the [Copernicus Climate Change Service](#) and [Climate Date Store](#) if sufficient long-term meteorological monitoring data is not available.
28. Use climate indices (e.g. North Atlantic Oscillation) to contextualise biological samples taken under different conditions (i.e., hot-dry, cool-wet, etc.). Use paleo-environmental reconstructions and other proxy evidence to represent the full range of conditions experienced at reference sites over multiple decades.
29. Undertake periodic reviews of conditions and pressures at reference sites to assess whether the site can still be used as a reference.
30. Be aware of the challenges associated with the attribution of environmental changes to anthropogenic climate change and avoid over-interpretation of observed trends.  
 Focus on how climate variability and change will interact with pressures from human activities to better plan measures. In many cases, climate change would aggravate the impacts of other human pressures, e.g. nutrient pollution, and more comprehensive measures would be needed to counteract the additional impacts caused by climate change.

#### 1044 5.2.2 Groundwater bodies

1045 The status assessment (both quantitative and chemical), the establishment of threshold values  
 1046 and the assessment of groundwater trends and trend reversal, according to WFD Annex V and

1047 its daughter Groundwater Directive (GWD), are tackled in detail by [CIS guidance document](#)  
1048 [No 18](#), which proposes a set of different tests. **The reflection of climate change effects within**  
1049 **the groundwater status assessment is rather related to the consideration of the relevant**  
1050 **climate change-affected pressures and indicators than to the assessment methodology**  
1051 **itself.** For example, consideration of groundwater temperature as an indicator of changing  
1052 biological and chemical processes could be relevant.

1053 WFD's environmental objective for good groundwater quantitative status is to ensure a balance  
1054 between natural recharge and abstractions and recharge (Article 4.1.b.ii). In addition, Annex V  
1055 2.1.2. (good status requirements) specifies the need for avoiding groundwater level alterations  
1056 leading to any damage to groundwater-dependent aquatic or terrestrial ecosystems or  
1057 alterations of flow directions resulting in saline or other intrusions.

1058 Although the WFD lays down the groundwater level as the metric for quantitative status  
1059 assessments, alternatively spring flow/discharges, baseflows of rivers and water balance  
1060 assessments are recommended. A groundwater quantitative status assessment is undertaken by  
1061 all MS to some extent in the form of spring flow measurements, in some countries for a  
1062 significant area of groundwater bodies, e.g. Austria. However, several countries also calculate  
1063 the volume of groundwater within groundwater bodies in addition to the spring discharge  
1064 volumes. These methods use a range of approaches, such as usable gross resource volume  
1065 estimation or sustainable yield. Others also calculate groundwater contribution towards surface  
1066 water ecological flows, typically using modelling approaches (Ireland, for example).

1067 **Applying groundwater level assessments might also need to consider the impacts of sea**  
1068 **level rise due to climate change**, which appears to be considered by MSs on a risk-based  
1069 approach. Countries that are likely to be significantly impacted by sea level rise already employ  
1070 detailed monitoring and assessment methods (e.g. Belgium, Malta, Netherlands, Portugal). In  
1071 other MSs, this characterisation is still in the research domain (Ireland). For other countries,  
1072 such monitoring can be ruled out for technical reasons, such as in parts of Sweden where post-  
1073 glacial isostatic rebound is currently outpacing measured sea level rise.

1074 The definition of a good quantitative status is focused on long-term issues, thereby implicitly  
1075 neglecting short-term effects, i.e. increased seasonal variation. This may need to be examined,  
1076 in particular when considering that e.g. groundwater dependent ecosystems can be significantly  
1077 damaged even by short-term drought events.

### 1078 5.2.3 Protected Areas

1079 Changes in the abiotic conditions of habitats (e.g. changes in water tables) can change the status  
1080 of protected areas such as NATURA 2000. Therefore, “special protection under specific  
1081 Community legislation for the protection of their surface water and groundwater or for the  
1082 conservation of habitats and species directly depending on water” is needed.

1083 The relevance of climate change on drinking water abstraction areas regarding Article 7 is  
1084 related to the impacts of more frequent and intense pollution events or higher variations of  
1085 water available that could arise from extreme weather events, altered (flash flood) runoff, and  
1086 increased water temperature. The pollution of water bodies or high alterations in the available  
1087 water amount does not only have an impact on the security of drinking water supply but further

1088 impacts ecosystems in the protected area (e.g. dwindling springs, low ground- and surface  
1089 water levels).

1090 The damage done to an ecosystem can in turn lead to long-term consequences, such as the  
1091 reduction of the natural self-purification effect of water, which can lead to higher treatment  
1092 costs. Low self-purification can also be directly related to low stream flows if structures to  
1093 provide sufficient water levels for agriculture or shipping are present. By implementing  
1094 protective measures in these zones, such as stricter controls on pollutant discharges, monitoring  
1095 and land use management, the vulnerability of protected areas to climate change-induced  
1096 stressors can be reduced.

1097 In the context of addressing climate change impacts on aquatic ecosystems and water resources,  
1098 the Natura 2000 network can play a significant role as a complementary measures. The efforts  
1099 of Natura 2000 with the provisions of the WFD, can support biodiversity conservation,  
1100 improved water management, climate change adaptation and resilience of protected areas. The  
1101 Commission also published a [Guidance Document](#) about adapting Natura 2000 areas to climate  
1102 change where further information is provided.

## 1103 5.3 Monitoring

### 1104 5.3.1 Monitoring of surface water

1105 Whilst monitoring programmes under the WFD are generally not designed to identify and  
1106 monitor all anthropogenic pressures like climate impacts, all additional long-term monitoring  
1107 programmes will inherently contribute to the detection and understanding of any climate  
1108 change signals. Also, the assessment of seasonal variations becomes more important in rivers  
1109 when a river changes from perennial to temporary because of climate change. Such rivers start  
1110 to fall dry over summer which has a huge impact on the biota. Monitoring becomes more  
1111 difficult though, because the timing of sampling becomes more critical and suitable time  
1112 windows become smaller. Equally, sampling during flood episodes can reveal pollutants  
1113 introduced by flood-related run-off and should therefore be carried out if it can be done safely.  
1114 Similarly, additional monitoring besides flooding and drought events should also be carried out  
1115 in the waterbodies downstream, as transitional and coastal waters.

1116 **It is very important to take a consistent and long-term approach.** Monitoring programmes  
1117 should be planned carefully with a long-term perspective and carried out consistently by  
1118 preventing major changes in the station network and/or in the implemented methodologies. It  
1119 is very important to avoid abandoning monitoring stations which already have a long-term  
1120 consistent record. Notwithstanding the above, it may be possible when designing monitoring  
1121 programmes to target reference sites (see section 5.4.4) or ‘hot spots’ of predicted climate  
1122 change impact when adding new stations.

1123 It is recommended to introduce the variable of uncertainty in the analysis and drafting of the  
1124 water balances as a result of the impacts derived from climate change. **Rather than choosing**  
1125 **a number on how much water will occur in future, start working with ranges of water**  
1126 **volumes in relation to its probability.** This needs to lead to different criteria in the decision-  
1127 making process for allocating resources for natural and human systems.

### 1128 5.3.2 Monitoring of groundwater status

1129 In the context of uncertainty, it is essential that monitoring is done to allow the type and scale  
1130 of adaptation response to be adjusted according to the level of climate (and socio-economic)  
1131 change experienced. Annex V of the WFD requires the quantity monitoring frequency and the  
1132 network to be sufficient to enable a reliable assessment of the quantitative status, taking into  
1133 account short and long-term variations in recharge and to assess the impact of abstractions and  
1134 discharges.

1135 Monitoring efforts should be also devoted to fast-changing and vulnerable groundwater  
1136 environments. They can include karst regions, shallow groundwater bodies, strong surface  
1137 water or glacier-dependent aquifer systems and coastal groundwater environments.

#### 1138 **Long-term data sets**

1139 Specifically for groundwater, the recommended guiding principle for WFD monitoring is to  
1140 ensure temporal continuity in both surface and groundwater monitoring sites, even if  
1141 groundwater abstraction at the spring or well is abandoned (e.g. for quality reasons); this holds  
1142 whenever a site is considered suitable for effective monitoring of climate change impacts. **It is**  
1143 **recommended to set up an investigative monitoring programme (a climate change**  
1144 **monitoring reference network as part of surveillance monitoring) for climate change and**  
1145 **for monitoring climate change ‘hot spots’** and to try to combine them as much as possible  
1146 with the results from the operational monitoring programme. This includes reference sites in  
1147 long-term monitoring programmes (e.g. focusing on areas without or with as low as possible  
1148 direct human impact) to understand the extent and causes of natural variability and the impact  
1149 of climate change. In order to detect climate change impacts early on, the monitoring frequency  
1150 might need to be higher than the WFD minimum for surveillance monitoring. Otherwise, it can  
1151 take a long time to gather robust time series.

1152 It is recommended to **integrate relevant climate change parameters in surveillance**  
1153 **monitoring programmes** to link climate change monitoring to existing long-term groundwater  
1154 monitoring. Parameters should be defined and harmonised and a clear distinction between  
1155 mandatory and optional ones should be made. Quantitative parameters (groundwater level,  
1156 pressure head, spring discharge, transfer between groundwater bodies, abstraction rates,  
1157 precipitation) as well as air and groundwater temperature are considered essential to establish  
1158 the water balance and to understand changes. Hydrogeochemical, surface water, snow and  
1159 glacier data or soil data can be relevant depending on the specific hydrogeological conditions.

1160 In most cases, long-term groundwater level or spring flow data sets are rare, and most MSs  
1161 appear to have completed research to identify existing records. It may be possible to reconstruct  
1162 historic groundwater level or spring flow data sets using modelling or proxy approaches, with  
1163 the appropriate caveats and characterisation of uncertainty clearly understood. Some MSs, such  
1164 as Sweden, have implemented this approach. Climate change-relevant data is often held by  
1165 water suppliers, communities or producers of hydraulic energy but is not accessible to water  
1166 authorities. Hence, it is necessary to open currently inaccessible data sets.

**1167 Extreme events monitoring**

1168 Improving the monitoring of the impact of extreme events (e.g. intense precipitation and  
1169 droughts) on groundwater-surface water interaction is important. Dedicated efforts should be  
1170 directed towards the collection of monitoring data capturing the effects of such events, which  
1171 are predicted to increase in frequency and intensity due to climate change. Additional  
1172 monitoring carried out during droughts typically comprises more frequent logger downloads,  
1173 citizen science initiatives to gather additional groundwater level data and low-flow spring flow  
1174 measurements. Remotely observed information could potentially support these observations.

**1175 Monitoring changing seasonal variations**

1176 The lack of monitoring and assessments regarding seasonal groundwater level dynamics can  
1177 be explained by the WFD's focus on annual averages. However, in many cases, climate change  
1178 may lead to a shift in the months with the highest and lowest groundwater levels, an increase  
1179 of amplitudes (higher and lower groundwater levels within a year), with associated ecosystem  
1180 stress, while not causing a changing trend in annual average groundwater levels. Local  
1181 requirements for increased frequency of monitoring or assessments of seasonal variations  
1182 should be guided by the location of reference monitoring sites and groundwater bodies that are  
1183 likely to exhibit such changes, based on the outputs of groundwater modelling work. In order  
1184 to properly monitor drought in groundwater, the existing observation networks should be  
1185 reviewed and modified accordingly.

**1186 Temperature sensitivity of groundwater recharge in simulation and observation**

1187 In a stationary climate, the amount of groundwater recharge depends on precipitation (mean  
1188 temperature constant). With climate change, the precipitation sensitivity is additionally  
1189 overlaid by the temperature or evaporation sensitivity (mean precipitation constant). To avoid  
1190 misinterpretations of water balance simulations, it is essential to consider the temperature  
1191 sensitivity of the applied water balance models. For this purpose, the different temperature  
1192 sensitivities in space and time from observations (lysimeters, water balances of catchment  
1193 areas) must also be analysed and considered. In Saxony (Germany), the temperature sensitivity  
1194 of the groundwater recharge in the period 1961-2020 was in the range of 15 to 60 mm/a  
1195 decrease per Kelvin temperature increase in approx. 100 catchment areas. Even if groundwater  
1196 recharge is plausibly simulated in the initial state, if water balance models underestimate the  
1197 temperature sensitivity, this leads to an overestimation of the simulated groundwater recharge  
1198 from the climate projections and incorrect groundwater levels.

**1199 Remote observation**

1200 Several MSs are using remotely observed information, typically obtained from the Copernicus  
1201 Programme. For example, in Ireland and Slovenia, satellite imagery is being used to monitor  
1202 the flood extent of karst lakes (turloughs in Ireland and Poljes in Slovenia). In some cases,  
1203 where the shoreline ground slope is a shallow gradient, it has been possible to use these  
1204 observations to produce flood hydrographs of turloughs in Ireland. In other MSs research is  
1205 underway to investigate whether remotely observed gravity data can be effectively used to  
1206 estimate groundwater volumes within aquifers and for drought monitoring and potentially  
1207 drought prediction. The responses indicate that remotely observed information is currently

1208 being used effectively to monitor at-surface phenomena related to groundwater quantity  
 1209 (groundwater flooding and groundwater irrigation) and that in future it may be possible to infer  
 1210 subsurface properties relating to groundwater quantity also. The potential cost savings and real-  
 1211 time provision of these data sources represent a significant opportunity to enhance groundwater  
 1212 monitoring across MSs, and most respondents indicated that they would be open to using such  
 1213 methods if and when they become available. Technical guidance on the use of remotely  
 1214 observed information or its incorporation into the CIS guidance document No. 7 on Monitoring  
 1215 under the WFD would support MSs in this activity.

#### 1216 **Protected areas monitoring**

1217 It is essential to apply appropriate monitoring techniques for acquiring information to  
 1218 effectively protect drinking water protected areas (DWPAs). Environmental tracers have  
 1219 successfully been applied for the evaluation of travelling times and trend assessments under  
 1220 the WFD and GWD in some MSs and helped to frame future policies for the protection of  
 1221 drinking water well fields and supported the derivation of effective threshold values for  
 1222 chemical status assessment and trend analysis.

1223 It is also recommended to implement an ecosystem approach in climate change monitoring by  
 1224 looking at both quantity and quality parameters in protected areas, to allow a sound assessment  
 1225 of climate change effects on groundwater and groundwater-dependent ecosystems. Current  
 1226 data in protected areas are typically too scarce and should be increased in time and space. The  
 1227 use of combined monitoring and modelling approaches should be promoted whenever possible.

31. Monitoring programmes within the WFD should provide an effective network for identifying and attributing changes in the water environment for validating risk of failure according to the WFD and assessing groundwater quantitative status, but in many MSs monitoring sites are under threat due to financial pressures. Water Directors should avoid, as far as possible, the decrease of monitoring and maintain stations with high-quality long-term records.
32. Maintain both surface and groundwater surveillance monitoring sites for a long time series. Set up an investigative high-resolution 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.
33. Do not systematically redesign monitoring programmes around climate change but, as part of general good practices, plan monitoring programmes carefully with a long-term perspective, assuring homogeneity and continuity in both the station network and the implemented methodologies. Do not abandon stations which already have a long-term consistent record.
34. Whenever possible, establish more intensive monitoring of vulnerable water bodies to better understand the pace and mechanisms of changes, and use these sites as sentinels of climate change. In all cases the minimum WFD monitoring frequency is applied, assess whether this is sufficient. In order to detect climate change impacts early, the monitoring frequency should be higher than the WFD minimum for surveillance monitoring.

#### 1228 **5.4 Exemptions**

1229 Article 4 of the WFD requires MSs to achieve good surface water status and good groundwater  
 1230 status at the latest 15 years onwards from the entry date the WFD comes into force but  
 1231 provides the possibility for time-related and other exemptions. Paragraph 4 of Article 4 allows

1232 a MS to postpone the achievement of the objectives for two subsequent RBMP cycles, i.e. up  
1233 to the end of 2027 (or beyond if the exception is justified based on natural conditions).  
1234 Paragraph 5 of Article 4 allows a MS to target less stringent standards when the achievement  
1235 of the full WFD objectives would be infeasible or disproportionately expensive. Paragraph 6  
1236 of Article 4 allows for temporary deterioration in the status of bodies of water only in  
1237 circumstances of natural cause or '*force majeure*' or the result of circumstances due to  
1238 accidents, which are 'exceptional or could not reasonably have been foreseen'. Paragraph 7  
1239 of Article 4 allows for new modifications to the physical characteristics of water bodies  
1240 leading to status deterioration or preventing the achievement of good status under certain strict  
1241 conditions.

1242 Whilst the use of exemptions is to some extent allowed under the WFD, this is subject to  
1243 thorough justification in line with the WFD. Exemptions are not a general option to cope with  
1244 the consequences of climate variability and climate change. Climate change can only be used  
1245 as a justification for exemptions in limited circumstances where there is convincing and  
1246 documented evidence and if all other conditions foreseen by the exemptions are met.

#### 1247 **Art 4.4 and 4.5 WFD**

1248 Climate change cannot be used as a general justification for exemptions under Articles 4.4 and  
1249 4.5, at least in the short term, i.e. in the absence of appropriate evidence that the changes making  
1250 it (technically) infeasible or disproportionately costly are the permanent result of documented  
1251 climate change. It is necessary to include long-term analysis in assessments (see Chapter 2)  
1252 and to base decisions on clear and substantial evidence, e.g. monitoring data (see section 6.5),  
1253 and not to aim for less stringent objectives only based on limited modelled assumptions and  
1254 exercises. However, there may be cases where there is sufficient evidence that the expected  
1255 scale of climate change impacts on pressures is large enough that the measures needed to meet  
1256 default objectives would be disproportionately costly or (technically) infeasible or that natural  
1257 conditions do not allow timely improvement in the status of the water body. Where climate  
1258 change is brought forward as the underlying reason for an exemption on the grounds of  
1259 disproportionate cost or (technical) infeasibility, a complete and robust evidence-based  
1260 analysis should be provided (e.g. use of more intensive monitoring of effects of measures in  
1261 vulnerable water bodies). For instance, trend detection is insufficient to invoke a change of  
1262 policy and process unless other elements are provided, such as the attribution of such a trend  
1263 to anthropogenic climate change. Details on the process and difficulties associated with the  
1264 attribution of changes to anthropogenic climate change are provided in the [literature](#). The  
1265 process for assessing the need for less stringent environmental objectives should therefore be  
1266 closely linked to the economic analysis of measures. Guidance on including adaptation to  
1267 climate change in economic analysis is given below in section 5.5.

1268 If applying an exemption under Article 4(5) with climate change brought forward as the  
1269 underlying reason, Member States still need to ensure the best status. Guidance document 20  
1270 (page 21) indicates that "a less stringent objective should represent the condition expected in  
1271 the water body once all measures that are feasible and not disproportionately expensive have  
1272 been taken".

1273 As Article 4(5) states one of the conditions is that MSs ensure no further deterioration, Member  
1274 States then also need to justify that the test on whether the environmental and socio-economic  
1275 need of the activity preventing the achievement of good status could instead be provided by  
1276 other means which are a significantly better environmental option not entailing  
1277 disproportionate costs has been passed. Since the exemptions have to be interpreted narrowly,  
1278 “other means” within the meaning of Article 4(5) have to be interpreted widely and include  
1279 other types of measures and measures in other locations.

#### 1280 **Art 4.6 WFD**

1281 There is evidence that extreme exceptional events, such as droughts, floods and surge tides will  
1282 occur more frequently and will be more intense. The effects of these exceptional events which  
1283 are exacerbated by climate change have been modelled with certain confidence and can be  
1284 modelled for national and regional purposes. However, the application of Art 4.6 may be  
1285 necessary several times in a row. Therefore, robust scientific evidence should determine on a  
1286 case-by-case basis whether they can still be considered exceptional and/or difficult to foresee  
1287 given their recurrence, as referred to in Article 4(6) of the WFD.

1288 In the context of the application of Article 4(6), it is crucial to avoid any confusion between  
1289 (unforeseeable) drought and (foreseeable) water scarcity. Water scarcity has a complex nature  
1290 in which the increase in agricultural water demands and other socio-economic water uses, as  
1291 well as inappropriate water management and planning (for example, over-allocation of water  
1292 resources), usually play a major role. Art. 4.6 refers to natural events (extreme floods and  
1293 prolonged droughts) that could not be reasonably expected and can also refer to an accident.  
1294 Even though water scarcity may be exacerbated by an unforeseen drought, water scarcity is not  
1295 caused by an extreme event such as an extraordinary drought. Therefore, where the main reason  
1296 is water scarcity because of ineffective water management, even if causing important  
1297 socioeconomic impacts, it could not be justified under Art. 4.6 and should be addressed within  
1298 the general strategies to improve climate adaptation and water resilience. A clear distinction  
1299 between drought and water scarcity is essential to avoid an inadequate application of Article  
1300 4.6.

#### 1301 **Art 4.7 WFD**

1302 The implementation of specific adaptation and mitigation measures, for instance, infrastructure  
1303 projects must generally support the achievements of the goals of the WFD. However, some  
1304 measures might require exemptions according to Article 4(7) of the WFD, i.e. if they may cause  
1305 deterioration of the status of affected water bodies or prevent them from achieving good status.  
1306 Certain adaptation measures to climate change e.g. storage basins and structural flood measures  
1307 can be counterproductive with respect to the WFD objectives in the sense that they may  
1308 deteriorate the status of one or more affected water bodies (or even result in collateral damage  
1309 of an ecosystem). Such measures or infrastructures, including water reservoirs, need to meet  
1310 all the conditions set in Article 4.7 of the WFD on new modifications. The processes set out in  
1311 [Guidance No. 36](#) - Article 4(7) exemptions to the environmental objectives need to be followed  
1312 as well as the preliminary rulings of ECJ (e.g. [Case C-525/20](#), [C-535/18C](#) and [C-461/13](#)).

1313 It should be noted that due to climate change additional or more stringent mitigation measures  
 1314 under Art 4.7 may be needed (e.g. measures to ensure appropriate e-flow). Once a project has  
 1315 been justified under Article 4(7) WFD, it may be necessary to re-classify the affected water  
 1316 body (e.g. as a heavily modified water body) or to apply a less stringent objective under Article  
 1317 4(5) WFD, subject to complying with the criteria set out therein. There should be no further  
 1318 deterioration after the infrastructure project has been implemented.

1319 Further, it is considered a good practice that any infrastructure project that falls under Art 4.7  
 1320 is also subject to climate-proofing under step 2 (see section 10.2) (e.g. a hydropower plant is  
 1321 not developing its full potential due to predicted changes in the flow regime in the medium and  
 1322 long future).

35. Avoid using climate change as a general justification in the context of exemptions, in particular, to lower objectives under Article 4(5), as climate change is seldom the only reason for not achieving the objectives; all steps and conditions set out in the WFD for the application of exemptions shall be duly followed.

36. Decide, on the basis of robust scientific evidence and a case-by-case basis, whether a prolonged drought or the effects of an extreme flood allows for the application of WFD Article 4.6, i.e. whether these events can be considered sufficiently unforeseeable/unforeseen in order to be suitable to justify a temporary deterioration (where the climate change projections are solid enough, the changes are likely to result in permanent rather than temporary deterioration); climate change projections must be taken into account in this case-by-case approach to decide on foreseeability or not (prerequisite for applying Article 4(6)).

37. Apply WFD Article 4.7 to new adaptation or mitigation measures that modify the physical characteristics of water bodies (e.g. reservoirs, water abstractions, dykes) in order to accommodate climate change impacts but where these may potentially deteriorate the water status. Take all practicable steps to mitigate the adverse effects of these adaptation or mitigation measures and thereby consider that due to climate change, more efforts might become needed.

## 1323 5.5 Economic analysis

1324 Changing climatic conditions do not modify the requirements and the steps in the  
 1325 implementation of the economic analysis of the WFD; in fact, they render the economic  
 1326 analysis even more useful. To profit fully from this exercise, it is even more important than  
 1327 before to follow the sequential steps as suggested in the outline of WFD Annex III but now  
 1328 with the integration of potential additional pressures, impacts and constraints due to climate  
 1329 change.

1330 WFD Annex III sets out that economic analysis should be carried out for two main issues in  
 1331 defining the RBMPs PoM, namely the recovery of costs of water services (taking into account  
 1332 long-term forecasts in supply and demand for water in the RBD) and for identifying the most  
 1333 cost-effective combinations of measures. In WATECO 2003 it is emphasised that “the  
 1334 economic analysis” in WFD covers more than just the economic analysis of water uses in  
 1335 Annex III to the Directive. Several of the results from the economic analysis of water use in  
 1336 Annex III to the directive are necessary inputs to the analysis of whether derogations to the  
 1337 environmental objectives are justified and in the analysis of heavily modified waters.

1338 MSs have taken markedly different approaches to the economic analysis, in regards to

1339 ambition, detail and analytical robustness, since the challenges vary considerably across river  
 1340 basin districts in the EU and also because the available resources and expertise differ  
 1341 (proportionate analysis). Inevitably, the way climate change needs to be integrated into the  
 1342 economic analysis must, therefore, be different as well. However, it is strongly recommended  
 1343 that the required long-term forecasts in supply and demand for water incorporate scenarios  
 1344 for climate change as these forecasts constitute the basis for most of the economic analysis  
 1345 and thus also the investment planning. There is thus a strong link to the “pathways” approach  
 1346 from section 4.3, but even with a less elaborated assessment framework, the use of multiple  
 1347 scenarios is generally recognised as a best practice in taking account of deep uncertainty. In  
 1348 assessing combinations of measures to meet the WFD environmental objectives, options  
 1349 should be sought that can be shown to perform (and be cost-effective) under a wide range of  
 1350 scenarios for future climate change.

1351 The justification to set an objective below good status (under WFD art 4(5)) for the current  
 1352 programming period should consider the impacts of climate change when assessing whether  
 1353 measures are infeasible or have a disproportionate cost. The latter requires a solid baseline  
 1354 mapping the consequences of climate change without the measures under scrutiny. For  
 1355 example, reducing water abstraction for irrigation might be seen as disproportionately costly  
 1356 because of its impacts on farmers and the local food and feed industry in the current  
 1357 programming period. However, these costs need to be seen in the proper context, namely set  
 1358 against the benefits of having water available for future agricultural activities in the long term  
 1359 (or other water-consuming activities if economically more worthwhile). The costs can only  
 1360 be deemed disproportionate when they would exceed the value of the measures with a wide  
 1361 margin (WATECO, 2003). On this basis, one needs to set the best possible status as a  
 1362 minimum objective without disproportionate costs. This approach is of vital importance in  
 1363 cases where water availability will change considerably over time and/or the water tariffs.

38. Explicitly consider climate change and the related uncertainty of its impacts when producing long-term forecasts of water supply and demand (including long-term trends and the adaptation strategies adopted in the water-demanding sectors).
39. Use multiple scenarios in the assessment of the effectiveness and costs of measures and the subsequent formulation of the most cost-effective package of measures, which would be best practice in many cases.

## 1364 5.6 Measures for adaptation related to the WFD

### 1365 5.6.1 Types of Measures and Principles for Selection

1366 The WFD requires PoM composed by the MS, to achieve its environmental objectives.  
 1367 Improvements in the status of water bodies within the framework of the WFD will only succeed  
 1368 if measures, which account for these types of climate changes, are taken in a timely manner  
 1369 and are climate robust.

1370 MSs have included several different measures in their RBMPs to achieve good status. They  
 1371 have been reported along 26 Key Types of Measures (KTMs) under WISE <sup>21</sup> and/or under the  
 1372 [KTMs](#) for Articles 17 and 19 of the EU Climate Law. Besides the KTM approach measures  
 1373 can broadly be further clustered along three types: grey, green and soft.

- 1374 i. Grey measures refer to technological and engineering solutions to improve the  
 1375 adaptation of a territory, infrastructures and people.
- 1376 ii. Green measures are based on ecosystem-based (or nature-based) approaches and make  
 1377 use of the multiple services provided by natural ecosystems to improve resilience and  
 1378 adaptation capacity. For example, the re-naturalisation of rivers contributes to flood  
 1379 prevention, climate adaptation and biodiversity conservation (See also Chapter 8).  
 1380 Their design and extent need to reflect new challenges related to climate change.
- 1381 iii. Soft options include policy, legal, social, educational, management and financial  
 1382 measures that can alter human behaviour and styles of governance, contributing to  
 1383 improve adaptation capacity and increase awareness of climate change issues. In this  
 1384 context, soft options encompass both social and institutional measures as described by  
 1385 the IPCC (2014).

1386 As good practice the measure selection should not only aim at achieving the objectives of the  
 1387 WFD but should also be taken to adapt (if relevant) to the pressures and impacts induced by  
 1388 climate change. In doing so, this should be done following Article 174 of the European Treaty  
 1389 which requires the precautionary principle and the principles that preventive action should be  
 1390 taken regarding environmental protection. Considering this fact there may be a need to consider  
 1391 whether additional measures are required to meet GES/GEP in changing climatic conditions.  
 1392 This is particularly not only the case where there are changes in physico-chemical conditions  
 1393 (e.g. to address invasive alien species that could not previously survive when water  
 1394 temperatures were lower).

1395 *Example 8: Priority and Reserved Areas for Groundwater Protection / Drinking Water Production.*

1396 Due to climate change, the already unfavourable water balance in some regions of Germany may further  
 1397 deteriorate. Altered precipitation and temperature conditions affect all processes in the water cycle, thus  
 1398 influencing the rate of groundwater replenishment and the quantity and quality of groundwater and  
 1399 surface water used for drinking water production. Increasing water scarcity and more frequent droughts  
 1400 can lead to regional conflicts over the use of primarily near-surface water resources.

1401 State and regional planning can designate priority and reservation areas for drinking water and  
 1402 groundwater protection to secure water resources, moderate between different usage claims, and avoid  
 1403 or mitigate conflicts. Almost 80% of planning regions make use of this possibility. The high proportion  
 1404 of regions designating these areas makes it clear that spatial planning instruments are not only used in  
 1405 planning regions that are generally affected by water scarcity. Rather, the protection and securing of  
 1406 water resources also hold significant importance in water-rich areas, as their water supplies are partly  
 1407 utilised to support water-scarce regions. Nationwide, in 2017, approximately 39,000 square kilometres  
 1408 of land were designated as priority or reservation areas for drinking water and groundwater protection,  
 1409 which accounts for more than 10% of the country's area.

---

<sup>21</sup> See also: WFD Reporting Guidance 2022 Annex 8q

1410 In general, a broad range of measures should be encouraged, and potential measures must not  
1411 be removed just because they currently are not feasible or desirable (Siebentritt & Stafford  
1412 Smith, 2016). Such options can become important at a later stage along the adaptation pathway.

1413 Further, already in 2008, the Water Directors agreed that the PoM should be climate-proof.  
1414 This assessment should analyse the impact changing climatic conditions may have on the  
1415 effectiveness of WFD PoM or individual measures for achieving the WFD objectives. The aim  
1416 should be to enhance the robustness of the PoM against changing climate conditions. Generally,  
1417 only measures that are robust to climate change impacts and do not contribute to climate change  
1418 should pass the climate check and should be considered in future RBMPs. However, this check  
1419 is also economically relevant as investments for the long term (e.g. building new or upgrading  
1420 urban wastewater plants) should be climate-robust.

1421 The implementation of measures must be coordinated at the proper spatial scale, fit the specific  
1422 local context and be compliant with international, national and subnational regulations and  
1423 plans and stakeholder adaptation needs. Even though implemented at the local scale, measures  
1424 often require coordination with higher levels of governance to ensure sustainable and  
1425 harmonised spatial planning of the whole region.

1426 Water managers preparing the PoMs also need to consider that other sectors will be introducing  
1427 climate measures which may have implications for water management. Without this awareness,  
1428 and where appropriate collaboration, there is an increased risk of maladaptation, also as some  
1429 other sectors do not require climate proofing.

1430 The WFD in Art. 11(3)(e) requires MSs to set up “controls over the abstraction of fresh surface  
1431 water and groundwater, and impoundment of fresh surface water, including a register or  
1432 registers of water abstractions and a requirement of prior authorisation for abstraction and  
1433 impoundment. These controls shall be periodically reviewed and, where necessary, updated.  
1434 MSs can be exempt from these controls, abstractions or impoundments which have no  
1435 significant impact on water status.” However, the last implementation report from the European  
1436 Commission shows that **although almost all MSs have a permitting regime or register to  
1437 control abstractions of groundwater and surface water, about half of all MSs reported  
1438 that small abstractions are exempted from controls.**

### 1439 5.6.2 Financing of adaptation measures

1440 The costs of achieving the environmental objectives of the WFD and the FD are significant. In  
1441 total, the capital investment costs of the measures planned in the 2nd RBMPs of the WFD reach  
1442 at least EUR 142 billion and the total flood risk mitigation costs planned in the 1st FRMPs  
1443 amount to at least EUR 14 billion. However, the overview of the costs of the planned measures  
1444 is heterogeneous and incomplete (European Commission, 2021a). Therefore, the costs  
1445 presented in this overview are likely to be an underestimate of the total costs incurred by the  
1446 MS.

1447 Financing and funding of measures is an important aspect of the planning process. Financial  
1448 limitations are often cited as a barrier to initiating and implementing adaptation actions at the  
1449 local level. However, adaptation funding and financing are available and can be combined from  
1450 various sources – international, EU, national and local, both public and private. Good

1451 knowledge of available funding opportunities is important for overcoming this barrier.  
1452 Mainstreaming adaptation into current planning processes and existing budgets is also an  
1453 important option to consider. An overview of potential funding mechanisms can be found in  
1454 [Climate-ADAPT](#) and the [EU Mission Portal](#).

### 1455 5.6.3 Cost recovery efforts

1456 Article 9 of the WFD indicates that MSs must take account of the principle of the recovery of  
1457 costs of water services, including financial, environmental and resource costs. These efforts  
1458 have to be informed by the economic analysis as outlined in WFD Annex III, and to be in  
1459 accordance with a proper application of the Polluter-Pays-Principle.

1460 However, Art 9 does not require full cost recovery, not even for the financial costs, as  
1461 authorities can set a lower recovery rate given the “social, environmental and economic effects  
1462 of the recovery as well as the geographic and climatic conditions of the region or regions  
1463 affected.” It is generally understood that the term “climatic conditions” does not provide a solid  
1464 legal basis to exclude water service’ cost recovery efforts all the cost pressures coming from  
1465 climate change.

1466 They are also required to define water-pricing policies, which provide adequate incentives for  
1467 users to use water resources efficiently and, in combination with the cost impacts of non-price  
1468 measures, imply “adequate contributions” of key water user sectors (exceeding the customers  
1469 of water services / their use of water linked to water services).

1470 Climate change will cause significant changes in the quality and availability of water resources.  
1471 The impacts are and will further manifest through changes and disruptions in local and global  
1472 water cycles and have significant effects on sustainable water resource management and thus  
1473 on water use throughout society and the economy. Although there are already visible climate  
1474 change effects on these water cycles, there is still significant uncertainty around how these  
1475 effects will occur at the regional and local level, as well as on the timing, magnitude and  
1476 location of specific impacts (Kerres M. et al., 2020). In many regions water authorities (will)  
1477 need to promote water use efficiency and stabilise and increase water supply (including through  
1478 storage, water recycling and desalination) as well as improve flood protection and water level  
1479 management (also in relation to protect and restore nature).

1480 While the WFD gives considerable degrees of freedom to water authorities on setting the rate  
1481 of cost recovery and the means to achieve it, the climate challenges necessitate a higher effort  
1482 to attain the WFD environmental objectives and warrant sufficient, affordable water for all and  
1483 for nature. It should spur water authorities everywhere to (re-)consider whether they make  
1484 effective use of all available policy instruments, including those related to water services’ cost  
1485 recovery (WFD art 9(1)). The long-term forecasts on water supply and demand (a mandatory  
1486 element of the economic analysis, as stated in WFD Annex III) should serve as the basis for  
1487 such policy (re-)assessments. Accounting for the “resource costs” of providing water services  
1488 in times of water stress provides a pertinent example. However, other water uses as well as the  
1489 PoM could be considered open for cost recovery efforts (often a good idea from an economic  
1490 perspective), but the WFD does not say anything about this.

1491 Hence, it can be expected that *ceteris paribus* the implementation costs of the RBMP's  
 1492 Programmes of Measures will increase, through larger investment needs and greater  
 1493 maintenance costs for providing water services as well as for other facilities directly tackling  
 1494 the climate impacts (on flood protection, regulating water level for energy generation or  
 1495 navigation purposes, and amenities such as to drain sealed surfaces and to protect vulnerable  
 1496 ecosystems). In general, it concerns measures to render water systems more robust to a broader  
 1497 range of potential hydrological conditions and change in pressures increased due to climate  
 1498 change as well as warranting minimal volume levels for essential water use such as in all cases  
 1499 drinking water supply. Widening the implementation of water tariffs and water-related charges  
 1500 enhances the efficiency of water (service) consumption and thus indirectly helps to avoid  
 1501 planning water facilities with a too large capacity and thus accommodating an unsustainable  
 1502 level of water consumption. Stable and transparent cost recovery arrangements facilitate  
 1503 unlocking untapped (private) sources of finance through innovating funding arrangements  
 1504 (including Payments for Ecosystem Services, Extended Producer Responsibility, or innovative  
 1505 fiscal policies, such as land value capture mechanisms) that can improve cost recovery for  
 1506 water services (OECD, 2022).

40. Take account of likely or possible future changes in climate when planning measures today in order to ensure the achievement of Good Ecological Status/Good Ecological Potential (precautionary approach).
41. Favour measures that are robust and flexible to the uncertainty and cater for the range of potential variation related to future climate conditions (no regret measures).
42. Choose sustainable adaptation measures, especially those with cross-sectoral benefits, and which have the least environmental impact, including GHG emissions. The adaptation measures having cross-sectoral benefits mean adaptation of behaviour or (regulatory) standards used in production processes in the most related sectors (building, urban planning, infrastructure, agriculture, forestry, navigation).
43. Avoid the structural changes of natural water bodies as much as possible, as the best resilience to face Climate Change is provided by natural systems. Make use of NBS and avoid creating water dependency by water reservoirs and/or artificialisation as this will lead to more artificialisation and is counterproductive for the water ecosystem (maladaptation).
44. Enforce sustainable and cooperative water allocation within and across basins. Start adapting water management to the present and future impact of climate change as soon as possible in water permitting and enforcement for abstractions.
45. Make use of good practice examples, e.g. from existing research and implementation experience regarding adaptation strategies and measures.
46. Use the WFD consultation process (Art. 14) to bring in sector-specific knowledge and data from key stakeholders and in particular vulnerable groups.

## 1507 **6 FLOOD RISK MANAGEMENT AND CLIMATE ADAPTATION**

1508 The FD foresees a 6-yearly cycle to establish a framework for the assessment and management  
 1509 of flood risks, aiming at the reduction of the adverse consequences for human health, the  
 1510 environment, cultural heritage and economic activity associated with floods. In the EU, the  
 1511 three key steps of the flood risk management cycle are PFRA, FHRM, and FRMP.

1512 Climate change should be taken into account throughout the flood risk management cycle. The  
 1513 FD states that the PFRA (Article 4, FD) shall, be based on available or readily derivable  
 1514 information such as records and studies on long-term developments, in particular the ‘impact  
 1515 of climate change on the occurrence of floods’ from the first cycle. Article 14.4 states that the  
 1516 ‘likely impact of climate change on the occurrence of floods shall be taken into account in the  
 1517 reviews [of the PFRA and the FRMP]’.

1518 This section of the Guidance will follow the three steps of the FD’s risk management cycle to  
 1519 propose ways how climate change could be incorporated.

47. According to Art 14.4; start adapting flood risk management to likely climate change as soon as information is robust enough since full certainty will never be the case. Follow the guiding principles set out for the [WFD](#).
48. Incorporate adequate resilient climate change scenarios in setting flood risk management objectives. In this process it will be necessary to communicate clearly the objective limits of possible public construction measures of flood protection.
49. Ensure coordination at the catchment level, (risk analysis, warming scenarios, potential measures, upstream/downstream impact of measures, warning), also respecting the Directive’s coordination requirements at RBD/unit of management level.
50. Include adequate resilient climate change scenarios in ongoing initiatives and the planning processes.
51. Favour options that are robust to the uncertainty in climate projections:
  - a. First focus on life protection of people in areas at risk of flash floods or storm surges.
  - b. Focus on pollution risk in flood-prone hazard zones.
  - c. Focus on non-structural measures (e.g. wetland restoration, giving rivers more space) when possible.
  - d. Focus on ‘no-regret’ and ‘win-win’ measures and use synergies with other objectives, e.g. reducing the effects of drought.
52. Favour prevention through the catchment approach, with special attention to the restoration of and/or the protection of water retention in the capillaries of the water system, to the infiltration in the soil feeding groundwater bodies/aquifers, to various wetlands, including the flood plains along all streams and rivers.
53. 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).
  - a. Include long-term climate change scenarios in land-use planning.
  - b. Develop robust cost-benefit methods which enable considering longer-term costs and benefits in view of climate change, including ecosystem services.
  - c. Use economic incentives (e.g. eco scheme payments, insurance, taxes) to influence sustainable climate adaptation in land use.
54. Assess other climate change adaptation (and even mitigation) measures by their impact on the flood risk:
  - a. Hydropower and flow regulation.
  - b. NBS solutions.
  - c. Link with water scarcity.
55. Pay special attention to the requirements of WFD Article 4.7 when developing flood protection measures.
56. Determine based on robust scientific evidence and on a case-by-case basis whether an extreme flood allows for the application of WFD Article 4.6.

57. Pay special attention to the vulnerability of protected areas in view of changed flood patterns.

## 1520 6.1 Preliminary flood risk assessment (PFRA)

1521 Article 4.2 of the FD states that the PFRA shall be carried out ‘based on available or readily  
1522 derivable information, such as records and studies on long-term developments, in particular  
1523 impacts of climate change on the occurrence of floods’<sup>22</sup>.

### 1524 **Using Climate models**

1525 It is important to understand the potential range of change in flood hazard and risk related to  
1526 the effect of different climate change scenarios. In order to facilitate global comparison  
1527 purposes, it is recommended to use official scenarios, like the IPCC AR 6 scenarios, as well as  
1528 the outcomes of national research and assessments. The IPCC AR6 considers five possible  
1529 future scenarios (Shared Socioeconomic Pathways (SSPs))<sup>23</sup>. The Coordinated Regional  
1530 Climate Downscaling Experiment (CORDEX) has also produced climate data at a higher  
1531 resolution. All these climate projections or data are available from [Copernicus](#).

1532 However, it can be challenging for MSs, water managers and flood risk managers to use the  
1533 raw outputs of climate change models, as there was a lack of guidance identified on how to  
1534 incorporate these effects in flood frequency estimations (European Commission, 2021b). Flood  
1535 frequency estimations are indeed still mostly undertaken by using methods based on a  
1536 fundamental assumption of stationary historical records for flood flows and/or precipitation  
1537 (Castellarin, et al., 2012), while natural climate variability and cycles are often not addressed  
1538 as the estimation of flood frequencies in a non-stationary climate remains scientifically  
1539 challenging.

1540 Therefore, it is recommended to liaise with the national or EU meteorological services<sup>24</sup> in  
1541 order to identify climate projections that should be used for the assessment<sup>25</sup>. For consistency,  
1542 the same range of projections should be used at a RBD level, and national level but also at a  
1543 local level to set a basis for the development of hydrological models. By considering more than  
1544 one scenario of future climate-related hazard projections, uncertainties can be better illustrated.

---

<sup>22</sup> In the context of the above-mentioned extension of time spans of usable records into history thorough analysis of available information on floods should be also considered, as it can be helpful for both the accuracy improvement of flood frequencies and for better understanding the impact of climate change.

<sup>23</sup> The IPCC AR6 considers five Shared Socioeconomic Pathways (SSPs), which explore possible futures, based on integrated assessment models (IAMs) of socioeconomic trends and associated climate, modelled by the World Climate Research Programme in CMIP5 and CMIP6. The IPCC previously only considered Representative Concentration Pathways (RCPs) of greenhouse gas emissions and associated climate, modelled by CMIP5.

<sup>24</sup> Go to [Climate-ADAPT](#) and then select your country from the dropdown list to go directly to the country's page. Then click on a tab on the right called “Contact”. The relevant contact details of the services will be shown if your country has reported them.

<sup>25</sup> Be aware that the properties of some physical processes that occur at a finer resolution than a model’s outputs are averaged. As such, you may be attracted to use downscaled model outputs but bear in mind that, in other ways, downscaling increases rather than decreases uncertainties.

1545 For planning purposes, it might be beneficial or good practice to consider future land use and  
 1546 uncertainties. These can have major impacts on flood flows, a possible direct effect on the  
 1547 impact of hydrological extremes (e.g. increased paved surfaces create higher flood risk peaks)  
 1548 but also on outlining new hazard areas (e.g. new building areas that might be affected by  
 1549 extreme floods). Although it can be difficult to distinguish between the effects of land use  
 1550 change and climate change on future floods, it may be necessary for MS to evaluate these  
 1551 drivers individually and consider their combined impacts on flood risk.

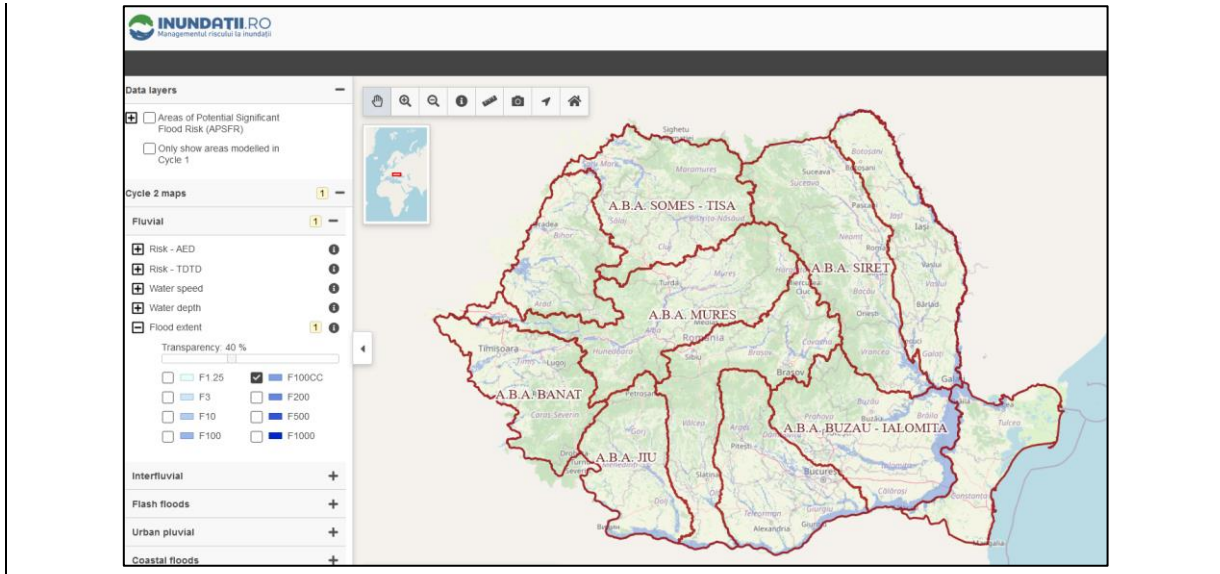
58. Understand and anticipate as far as possible increased exposure, vulnerability and (flash)flood risk due to climate change, for establishing areas of potential significant flood risk.
59. When delineating various flood scenarios, take into account the impact of climate change over a time span of at least 50, and preferably 100 years.
60. While not a requirement of the FD, use the 6-year review of flood maps if data is robust enough to incorporate climate change information explicitly covering an adequate time horizon of 50 and 100 years for different frequencies of occurrence.
61. Recognise the combined impacts of both anthropogenic changes (e.g., land use and hydro-morphological alterations) and climate change on future flood risks, acknowledging uncertainties, their interplay and assessing their effects on flood risk.
62. Stimulate collaboration between (inter-)national research institutes and climate services to further develop local-scale climate information (especially in countries with currently limited capacity).
63. Improve the collection and sharing of flood losses with high spatial and sectoral detail and use this information in the construction of their flood loss models.
64. Consider intensifying the cooperation between insurance companies, flood managers and stakeholders.

## 1552 6.2 Flood hazard and risk maps (FHRM)

1553 MSs are not mandated to show the influence of climate change on floods in the maps. However,  
 1554 showing the changes in the flood extent of the different climate scenarios would support  
 1555 awareness raising significantly for areas identified in consecutive cycles.

### 1556 *Example 9: FHRM in Romania*

1557 Romania provides in its [FHRM](#) besides different scenarios one dedicated to climate change (F100 cc).  
 1558 To estimate the impact of climate change on maximum river discharge a scenario with 0.1% flooding  
 1559 probability was used. Romania compared the projections for 2021-2050 with the reference period 1970-  
 1560 2000. Three classes of changes were considered: (1) regions where maximum discharge will not change  
 1561 (stationary), (2) regions with a moderate increase of maximum discharge (10%) and (3) regions with a  
 1562 significant increase of discharge (20%).



1563

1564 Even if some progress has been made with regard to uncertainties in climate projections and  
 1565 the methods to consider them in the context of the FD, further development of analytical  
 1566 methods to assess flood hazards in a changing climate and cartographic methods are still  
 1567 important, as they may help to visualise probabilities and uncertainty in flood-mapping  
 1568 products. Further development of mapping methodologies, technologies and tools would also  
 1569 help combine the differences in projections. This would help in terms of knowing where flood  
 1570 patterns are expected to change with climate change, regarding fluvial, pluvial floods  
 1571 (urban/rural), coastal floods, extreme river floods, flash floods, groundwater floods, ice jams  
 1572 and frazil ice floods, etc.

### 1573 6.3 Flood risk management plans

#### 1574 6.3.1 Flood risk management objectives

1575 Article 7 of the FD requires MSs to establish appropriate objectives, ‘focusing on the reduction  
 1576 of potential adverse consequences of flooding and, if considered appropriately, on non-  
 1577 structural initiatives and/or the reduction of the likelihood of flooding’. The FRMP shall  
 1578 include measures to achieve these objectives. All EU countries according to their conditions  
 1579 and specific geographical region, are thus required to take adequate and coordinated measures  
 1580 to reduce flood risk at all governance levels, and ‘focusing on prevention, protection,  
 1581 preparedness, including flood forecasts and early warning systems and take into account the  
 1582 characteristics of the particular river basin or sub-basin’. The likely impact of climate change  
 1583 on floods shall also be considered in the review of the plans (Article 14 (4)).

#### 1584 6.3.2 Measures for adaptation related to the FD

1585 The measure selection should consider long-term perspectives, favouring prevention through  
 1586 the catchment or sub-catchment approach, and options that are robust to the uncertainty of  
 1587 climate projections (focusing on communities, critical infrastructure and pollution risk in flood-  
 1588 prone zones, non-structural measures, ‘no regret’ and ‘win-win’ measures as well as on mixes  
 1589 of measures).

1590 Further when establishing measures, according to Article 9 of the FD, FRMP should take into  
 1591 account and be in coordination with the general and environmental objectives of the WFD  
 1592 (reach ‘good status’ in water bodies) to improve the synergies between the two directives, as  
 1593 well as the objectives of the European Green Deal, the EU Climate Law and the EU energy  
 1594 policy (e.g. the Governance of the Energy Union and Climate Action Regulation). And vice  
 1595 versa the measures in the WFD programmes of measure shall take into account all the  
 1596 information that is provided from the FD 3 steps. It is also important when defining and  
 1597 implementing the measures to be put in place to counter flood risks, and in particular grey  
 1598 infrastructure<sup>26</sup>, to consider the environmental consequences and to prioritise where possible  
 1599 sustainable and no-regret solutions with a view not only to the short-term but also to the  
 1600 medium and long term. The public safety aspects of flood risk management also need to be  
 1601 further emphasised, in particular regarding civil protection measures and crisis management.  
 1602 Considering the multiple benefits, the restoration of wetlands and the improvement of the  
 1603 resilience of ecosystems is key to climate change adaptation (see also Chapter 8).

1604 In case of extreme and sudden weather events, causing the risk of flooding, cross-border  
 1605 communication needs to be instantly set up and actions, especially in the upstream country,  
 1606 need to be synchronised (agreed) to minimise risks and potential damage.

1607 In addition to these aspects, adopting the following approaches is recommended when it comes  
 1608 to developing FRM measures.

### 1609 6.3.3 Adopting an integrated approach

1610 Comprehensive policy frameworks, such as Integrated Flood Management, are based on risk  
 1611 management principles that explicitly recognise the residual risks on the floodplains while  
 1612 taking a comprehensive perspective of floods, river health, as well as benefits and risks of  
 1613 floodplain use. The development of a holistic integrated FRM is a key issue for the adaptation  
 1614 to climate change, as it draws a link between economic and social development, environmental  
 1615 protection and strengthens the resilience of nature and society to extreme weather events. There  
 1616 are several principles for the development of integrated flood management plans:

- 1617 i. Managing the water cycle as a whole, improving stakeholder participation.
- 1618 ii. Adopting a mix of best measures (including nature-based and ecosystem-orientated solutions)  
 1619 with a multi-disciplinary approach.
- 1620 iii. Better integrating water and land management<sup>27</sup>.
- 1621 iv. Developing risk-informed decision-making and preventive measures<sup>28</sup>.

---

<sup>26</sup> Grey infrastructure can damage biophysical and hydrological processes, seal soils and buried streams. Compared to grey physical infrastructure, natural infrastructure is often more flexible, cost-effective and can provide multiple societal and environmental benefits simultaneously (McVittie et al., 2018; UN Water, 2018; IPBES, 2019).

<sup>27</sup> See also the [EU Soil Strategy](#) regarding soil protection and prevention of flash floods.

<sup>28</sup> MSs and local authorities, as well as flood and water managers, are strongly invited to consult the [Guidance Document](#) by the WMO in 2017 and the EEA report on NBS (EEA, 2021a) for detailed information.

1622 v. Harmonising flood prevention measures, including those included in FRMP, with the water  
1623 scarcity and drought prevention measures included in RBMPs.

1624 In this respect, the EEA (2021a), offers solutions that should be implemented by MSs and local  
1625 authorities, in line with the Integrated Flood Management principles. It develops case studies  
1626 of the effectiveness of nature-based responses to (flash) floods in Annex 4 (A4.1 and A4.2).  
1627 Chapter 9 of this guidance document is also dedicated to nature-based solutions.

#### 1628 6.3.4 Awareness raising, early warning and preparedness

1629 Sensitising the EU's population to climate change and risks, especially floods, is still a work  
1630 in progress as the assessment of the 2nd FRMPs shows. All MSs and stakeholders must support  
1631 the encouragement to raise awareness and the necessity of self-protective measures for citizens  
1632 about an increasing risk of floods due to climate change, through available FHRM for the  
1633 public. Public digital flood viewers which are applied in most MSs are a useful approach  
1634 towards awareness rising. Furthermore, education and press campaigns on different scales that  
1635 are easy to follow should promote the necessity of adapting and building suitable protection  
1636 against floods. Local (planning) authorities, as well as private actors, should be involved to  
1637 raise acceptance of measures and combine them with other climate adaptation mechanisms  
1638 possible.

1639 In October 2023, the Commission published a new [flood risk areas viewer](#) to raise awareness  
1640 about potential significant flood risks. The viewer is provided with the support of the EEA and  
1641 reflects work carried out by the MSs under the [FD](#). Users can zoom in to see which areas of  
1642 potentially significant flood risk have been identified by each MS. The MSs themselves define  
1643 what constitutes a significant flood risk. By clicking on the map, users can display relevant  
1644 information and links to the MS' PFRA, FHRM and FRMP.

1645 It is important to draw the link between flood risks and other hazards, advocating for  
1646 coordinated emergency measures to reduce the overall risk. Climate change is leading to an  
1647 increase in the number and intensity of hydrometeorological hazards, which makes the  
1648 improvement of civil protection necessary. Particular attention should be drawn to warning  
1649 systems, institutional and material preparedness at the local, EU and MS scales (in the case of  
1650 simultaneous and large-scale events).

#### 1651 6.3.5 Improving the process of integrating climate change science into flood risk 1652 management practice

1653 To facilitate research related to FRM and cooperation between scientists, flood risk managers  
1654 and policymakers, specific platforms at national and/or regional (i.e. pan-European or large  
1655 transboundary river basin) scales should be reinforced (European Commission, 2021b).

## 1656 7 DROUGHT MANAGEMENT AND CLIMATE ADAPTATION

1657 Although temporary droughts are a characteristic of certain climate zones such as the  
1658 Mediterranean, droughts and (subsequent) water scarcity can significantly affect the  
1659 environment, economy and society.

1660 Due to climate change, the risk of long periods with no precipitation in combination with higher  
 1661 evaporation due to temperature rise and heat waves will increase in large areas of Europe. The  
 1662 increased frequency, length and intensity of droughts requires dedicated efforts and responses  
 1663 in terms of preparedness, sustainable water management and reduction of water consumption.

## 1664 7.1 River basin management plans and drought management plans as tools for 1665 addressing water scarcity and droughts

1666 According to the WFD, RBMPs are an appropriate framework to deal with unsustainable water  
 1667 use leading to water scarcity. They shall include explicit references to drivers and pressures of  
 1668 water scarcity, as well as corresponding status assessment references (in particular to the  
 1669 hydromorphological status of surface water bodies and the quantitative status of groundwater  
 1670 bodies). RBMPs shall also include measures to reduce significant abstraction pressures,  
 1671 incentivise efficient use via water pricing, manage water demand, promote efficiency, reuse,  
 1672 desalination, manage aquifer recharge, education, etc. for achieving the WFD environmental  
 1673 objectives. Most measures – for which the Commission establishes a [hierarchy of action](#) – can  
 1674 also be considered as a contribution to enhanced preparedness and resilience towards drought  
 1675 events.

1676 RBMPs can also contribute to mitigating the effects of droughts. The European Commission  
 1677 recommends establishing specific DMPs (European Commission, 2019; European  
 1678 Commission, 2021c). The European Council recognised their usefulness (European  
 1679 Commission, 2010) and called for the improvement of water scarcity and drought management  
 1680 strategies. However, DMPs can have the format of a chapter in the RBMP or stand-alone  
 1681 documents or be integrated into other relevant strategies (e.g. adaption strategy) adopted by  
 1682 MSs to manage water scarcity and drought events (Schmidt, et al., 2023). Independent from  
 1683 the format, three key elements should be included in these strategies:

- 1684 i. Indicators and thresholds establish the onset, ending, and severity levels of exceptional  
 1685 circumstances (drought).
- 1686 ii. Measures are to be taken in each drought phase to prevent deterioration of water status and to  
 1687 mitigate negative effects.
- 1688 iii. An organisational framework to deal with drought and subsequent revision and updating of the  
 1689 existing DMPs.

1690 Indicators shall ideally also build on the drought indicators set by the European Drought  
 1691 Observatory, as this can ease transboundary and pan-European management of droughts; as  
 1692 well as on the Water Exploitation Plus index compiled by Member States and the EEA for  
 1693 water scarcity. Monitoring of drought impacts is encouraged to foster further preparedness, as  
 1694 well as to take the appropriate relief and response measures.

1695 Several drought management approaches are currently in place – some define the priorities for  
 1696 actions, including water resource management (to ensure adequate distribution of resources,  
 1697 e.g. water supply), ecosystem conservation strategies (aiming for the protection of ecosystems,  
 1698 habitats or species, and ecosystem services), risk management (focusing on the stepwise  
 1699 application of preparedness, mitigation, relief and restoration measures during a drought event,  
 1700 and/or addressing the hazard, exposure and vulnerability), climate adaptation (with droughts

1701 as one component of such strategies, also possibly addressing heat waves and wildfires), and  
 1702 sector-focused management.

*Example 10: Drinking Water Security Plan*

In July 2023 the Austrian Ministry published a [Drinking Water Security Plan](#), which was developed in coordination with the 9 federal states to develop a programmes to ensure future drinking water security. It contains a guide in dealing with drinking-water shortage and a 5-point, long-term programmes including the improvement of the data basis and forecasts for planning and preparations for measures, the promotion of research for efficient water use, awareness-raising activities for the careful use of drinking water, secure financing of the drinking water supply in the long term, and a regular evaluation of drinking water supply concepts.

1703

*Example 11: Spain's Drought Management Plan*

Like many other European MSs, Spain has traditionally managed droughts as a crisis only by applying emergency procedures and urgent measures (through the adoption of Emergency Drought Orders or Decrees). However, that approach failed to achieve the most sustainable and cost-efficient solutions in the long-term. After the devastating environmental, social, and economic consequences of the 1991–1995 drought period, a paradigm shift towards a drought risk-reduction management approach in Spain was necessary. Since 2001, Spain's government has established hydrological indicators to help River Basin Authorities identify a looming drought situation early enough.

Based on guidance documents of the Spanish government, RBA adopted DMPs for the first time in 2007. Since then, these DMPs have been updated in synch with the RBMPs, every six years. Like the RBMPs, the DMPs are also subject to public consultation, allowing stakeholders from water-consuming sectors to provide inputs and include principles and measures to address drought risks, including the possibility of a reduction to minimum ecological flows during severe droughts.

Spain's DMPs differentiate drought events from water scarcity episodes in terms of root causes, consequences, and required actions to deal with each scenario. Temporary water scarcity, because of droughts, is dealt with in DMPs. Permanent water scarcity, not due to droughts, but because of inappropriate water management (which of course can be exacerbated due to droughts) is to be addressed in the RBMPs. In addition, the Spanish legislative framework states that local authorities in water supply systems with more than 20.000 inhabitants must establish and implement emergency plans in case of droughts (Hervás-Gómez & Delgado-Ramos, 2019).

1704

1705 The state of the art of drought management planning presupposes forecast models in addition  
 1706 to only using historical probabilistic precipitation, flows, reservoir storage and piezometric  
 1707 level information (Hervás-Gómez & Delgado-Ramos, 2019). With the increasing availability  
 1708 of data on droughts at regional and national levels, and the modelling of climate impacts in  
 1709 national and regional climate adaptation strategies, the relevant authorities shall share a  
 1710 common framework in terms of data, impact modelling and mitigation scenarios across  
 1711 different sectors. Water managers shall increasingly use predictive models to anticipate and  
 1712 evaluate future impacts of a drought.

1713 Specific drought management relief and response measures are implemented by the MSs  
 1714 (Schmidt, et al., 2023). Most of them are operational demand and supply measures, followed  
 1715 by economic impact compensation measures, increased control and enforcement measures,  
 1716 operational measures for the environment, and organisational measures. Only a few MSs

1717 foresee and implement follow-up and recovery measures after a drought, which makes it more  
1718 difficult to improve over time.

1719 Water allocation priorities under droughts are in place for more than half of the MSs (Rouillard  
1720 & Schmidt, 2023). Priority water allocation schema shall be based on, among other factors,  
1721 recent water accounts for the RBD (European Commission, 2015), which improves the  
1722 accountability and transparency of the administrative action. The level of complexity and detail  
1723 can be related to the severity of the water scarcity, including possible water use restrictions  
1724 affecting more than the water use sectors. The ranking criteria often reflect the societal  
1725 relevance, economic importance, and ecosystem values related to water, but do not use criteria  
1726 of sustainability, efficiency and/or equity. It is strongly recommended that the ranking system  
1727 includes the implied price differential between sectors caused by the allocation quantity  
1728 decisions as a key factor.

65. Use the WFD to achieve climate change adaptation preparedness in areas of water scarcity and to reduce the impacts of droughts, e.g. achieving good quantitative groundwater status supports a more climate-resilient water system.
66. In areas under relevant drought risk, adopt appropriate strategies aligned with the principles of DMPs (previously identified indicators and thresholds, measures and governance frameworks), to handle drought situations.
67. Ensure the consistency of sector-specific strategies with plans and measures for drought preparedness and emergency management.
68. Ease transboundary and pan-European management of droughts by using a common set of indicators, ideally based on the drought indicator set of the European Drought Observatory.

## 1729 7.2 Monitoring and detecting climate change effects on droughts and water 1730 scarcity

1731 Many EU MSs do have monitoring systems in place, addressing climate change, water and  
1732 droughts (Rouillard & Schmidt, 2023), from national to local scale. In addition, the European  
1733 Drought Observatory (EDO) was initiated by the European Commission's Joint Research  
1734 Centre (JRC) in 2008 and, since 2018, has been part of the Copernicus Emergency  
1735 Management Service (CEMS), providing up-to-date information on the evolution, occurrence  
1736 and forecasting of droughts in Europe. EDO publishes maps of updated indicators and follow-  
1737 up reports on the most severe episodes. CEMS is part of the Copernicus programme services  
1738 and supports all actors involved in managing natural or manmade disasters by providing  
1739 geospatial data and images for informed decision-making, based on an agreed indicator set.  
1740 Furthermore, the EEA provides updated information about the evolution of water consumption  
1741 in European river basins. This information is based on the Water Exploitation Plus Indicator,  
1742 based on information from the MSs. In line with the adoption of the new EU Strategy on  
1743 Adaptation to Climate Change from 2021, the European Commission (DG Environment and  
1744 the JRC) launched the European Drought Observatory for the Resilience and Adaptation  
1745 project (EDORA), aiming to improve drought resilience and adaptation throughout the EU.  
1746 The JRC published a Drought Risk Atlas which includes methodologies of the impact chains  
1747 and quantitative risk estimations developed and can be transferred to other scales (e.g. MS,  
1748 river basins). This allows the use of more detailed information and high-quality data and

1749 enables targeting specific systems and impacts that are particularly relevant for the respective  
1750 context (Rossi, et al., 2023).

69. Diagnose the causes that have led to droughts or water scarcity in the past and/or may lead to it in the future.
70. Monitor water abstraction and consumption closely and create forecasts based on improved knowledge of demands and trends. Distinguish climate change signals from natural variability and other human impacts with sufficiently long monitoring series.
71. Use detailed, up-to-date information, maps and early warning systems available from European, national, regional and local levels, including EDO, CEMS, and EEA, ensuring timely and informed decision-making in response to drought events.

### 1751 7.3 Adaptation measures related to water scarcity & droughts

1752 Adaptation measures should be based on proper risk assessments under current and future  
1753 climate conditions and should follow a water-smart economy and society approach. This means  
1754 that all available water resources, including surface-, ground-, rain-, waste-, and process water,  
1755 are managed in a way to avoid water scarcity and pollution. Such actions could demonstrate  
1756 resource-efficient solutions derived from the systemic exploitation of symbiotic inter-linkages  
1757 between wastewater treatment in industries and water utilities.

1758 The optimal combination of measures should be based on a cost-effectiveness analysis  
1759 considering the expected socioeconomic and climate change scenarios. In addition to the direct  
1760 (water volumetric) benefits – which can be primarily measured in terms of improving the water  
1761 balance – multiple other considerations must be factored in, such as local natural and social  
1762 conditions, the provision of other co-benefits and/or the avoidance of maladaptation and  
1763 negative externalities, and the persistent effect of achieved efficiency improvements on water  
1764 consumption.

1765 For example, negative externalities might occur when water reuse is practised as a measure to  
1766 mitigate the impacts of water scarcity. However, river bodies receiving a high share of  
1767 wastewater effluent might be adversely impacted when the effluent is reused instead of being  
1768 discharged into the stream. Thus, environmental flows shall be considered when assessing  
1769 water reuse as an option.

#### *Example 12: Digitalisation of Spain's water cycle*

The Government of Spain has allocated 200 million € of the Recovery and Resilience Facility to digitalise the water cycle in irrigation water user associations through a competitive process. The programme aims at completing the identification of water uses for irrigation, promoting transparency, improving efficiency, rationalising the use of agrochemicals to improve water quality and optimising the use of energy. Successful applications will use digitalisation to build information systems used for local irrigation management, real-time measures and report water abstractions and allocations, monitor the quality of irrigation return flows, supervise soil water and fertilizer leaching in irrigated areas, and introduce renewable energy for water pumping.

1770

#### *Example 13: ADAPT2CLIMA Decision Support Tool*

The [ADAPT2CLIMA Decision Support Tool](#) aims to enhance the understanding of climate change and its impacts on agriculture in order to support farmers, policymakers and other relevant

stakeholders (agronomists, agribusiness industry, etc.) in adaptation planning. The tool is currently applied in Cyprus, Crete (Greece) and Sicily (Italy) to visualise the crop performance water availability in relation to climate change via maps and graphs using the tool. Moreover, the tool may be applied to explore the available adaptation options for addressing climate change impacts and their efficiency in increasing resilience in agriculture.

1771

72. Limit future water abstraction and consumption to use-relevant projected availability under relevant climate change scenarios.
73. Follow an integrated approach based on a combination of measures.
74. Interconnect urban water supply systems.
75. Engage stakeholders to produce decisive measures to tackle water scarcity.
76. Assess other climate change adaptation and mitigation measures according to their impact on water scarcity and drought risks to avoid maladaptation and promote synergies.
77. Have authorisation regimes and regularly updated registers for all types of water abstractions including small ones. Monitor the cumulative impacts of several abstractions and their impacts on other environmental legislations including the Nature Directives.<sup>29</sup>
78. Ensure that any new impoundments such as water reservoirs are conditional to an Article 4.7 test under the WFD, including a proper justification. No artificial impoundments or reservoirs (other than natural water retention measures) should be built in or impact protected rivers, wetlands and habitats, including Ramsar sites, Natura 2000 sites, ecological corridors, and other types of protected areas recognised at local, national or international levels.
79. Develop water use efficiency, saving and consumption targets for all water users, at the sub-basin or basin level.

#### 1772 7.4 Priority Water Allocation under water scarcity conditions

1773 Water allocation mechanisms<sup>30</sup> can be defined as the combination of institutions which enable  
 1774 water users and water uses to take or to receive water for beneficial use according to a  
 1775 recognised system of rights and priorities. These mechanisms define who is allowed to access  
 1776 water, how much may be taken and when, how it must be returned, and the conditions attached  
 1777 to the use of the water. In addition, allocations must account for the range of uses needing  
 1778 specific flows or levels of water in rivers and lakes such as the environment, navigation,

---

<sup>29</sup> When granting authorisations for water abstraction, Member State authorities should systematically take into account the status of the water body concerned, and the foreseeable trends in water availability. This should include the expected effects and uncertainties resulting from climate change, as well as the direct and indirect impacts of the abstraction on the water body (including on the ecological status of the surface water body, i.e. fish populations, and the quantitative status of the groundwater body). Water planning needs to include a climate change uncertainty analysis, in order to define risk scenarios that can help set the maximum annual (or monthly) quantity that may be abstracted.

<sup>30</sup> The CIS Ad Hoc Task Group Water Scarcity & Droughts discussed the contribution of water allocation mechanisms to the WFD and the role of water allocation mechanisms for mitigating climate change impacts during the 2020-24 mandate based on the report “Implementation of water allocation in the EU”, available for download [here](#). From this work, a number of general principles emerged that can be seen as good practice to adapt water allocation regimes to climate change. These recommendations are – like CIS Guidance in general – non-binding for EU Member States.

1779 recreational users including anglers, water-based tourism and fisheries. **Allocations can be**  
1780 **issued in different forms:** permits, time-limited allowances or long-term or permanent  
1781 entitlements – or a combination of those when for instance permits are modulated by annual or  
1782 seasonal restrictions.<sup>31</sup>

1783 Water allocation regimes can pursue several competing objectives: economic efficiency,  
1784 environmental sustainability and social equity.

1785 Economic efficiency is concerned with allocative efficiency, that is allocating water to the  
1786 highest economic value uses. Environmental sustainability aims at the hydrological integrity  
1787 of the system. In the European Union, these are determined by the legally binding objectives  
1788 of Article 4 of the WFD for achieving a good status of surface and groundwater bodies. Social  
1789 equity objectives finally strive to achieve some level of social justice between user groups. For  
1790 instance, access to drinking water is considered to be a human right.

1791 Obviously, depending on each EU Member State's policies, the emphasis of one aspect above  
1792 another aspect will differ. However, to some extent, all three objectives can be found in water  
1793 allocation regimes, as all MSs strive to somehow balance economic, environmental and social  
1794 needs. How this balance is struck will strongly be influenced by historical circumstances that  
1795 have shaped existing allocation arrangements, the relative weight given to certain policy  
1796 objectives over others, and the prevailing political orientation (OECD, 2022a).

1797 In the European Union, the WFD establishes implicitly that the water balance is the foundation  
1798 for determining sustainable abstraction levels given available renewable freshwater resources  
1799 based on requirements for *ecological flows*. Only once sustainable abstraction levels are  
1800 known, by identifying ecological flows, water managers can identify a surplus that is subject  
1801 to allocations for different use cases. **Establishing ecological flows is therefore a starting**  
1802 **point for WFD compatible sustainable water allocation regimes.**

1803 Under the WFD, MSs are required to establish controls on the use, abstraction and discharge  
1804 of water (Art. 11.3) in the form of registers and prior authorisation through permitting regimes.  
1805 Permits are a key tool to implement WFD-compliant allocations. While registration, metering  
1806 and/or licensing/permitting of water abstractions are carried out by nearly all MSs, most of  
1807 them have **not yet sufficiently taken into account potential climate change risks within**  
1808 **their abstraction regulation processes.** Specifically, which regulatory actions are required  
1809 when drought and severe water stress occur, and which ones to adequately anticipate such  
1810 events. This represents a clear opportunity to achieve adaptation goals and improve resilience.  
1811 To deal with water scarcity, several affected MSs have defined priorities for water allocation  
1812 under drought or water scarcity conditions. The widespread occurrence of severe and prolonged  
1813 droughts in Europe in the last years has given prominence to the issue.

1814 These priorities decide which users can use the resource when supplies are not sufficient to  
1815 meet all demands. However, water scarcity occurs whenever the demand exceeds the available  
1816 resources, be it through changes in physical availability or demand-side stress. Consequently,

---

<sup>31</sup> See the report "Implementation of water allocation in the EU", page 9, available for download [here](#).

1817 and under an uncertain climate future, regions that have so far been spared by droughts can  
 1818 benefit from proactively thinking about water allocation priorities. Such allocation mechanisms  
 1819 can support effective management to maintain ecosystem health when imbalances between  
 1820 demand and supply or droughts occur and provide clarity for affected stakeholders.

1821 How to set priorities, however, is a complex task, that depends on regional hydrological  
 1822 conditions and needs as well as the specific legal and regulatory context. There is no one-size-  
 1823 fits-all hierarchy, and water managers face questions of sustainability, social equity, flexibility,  
 1824 and feasibility, among others. Although not a requirement under the WFD, this section shall  
 1825 provide preliminary guidance on how to define water allocation priorities to be prepared for  
 1826 scarcity conditions and grant planning security for stakeholders.

*Example 14: Priority water allocation*

16 MSs currently have priority water allocations during water scarcity. Many are established on a national level, while some MSs grant authority within the national priorities to regional management or RBD levels, embracing regional contexts (Schmidt, et al., 2023).

1827

*Example 15: Overarching principles that steer prioritisation in Flanders*

In 2022, the [Flemish Government](#) defined in discussion with stakeholders several overarching principles that steer prioritisation, as well as binding boundary conditions that place the highest absolute priority on certain needs (in this case dykes, sensitive nature and navigation). Subsequently, Flemish sub-areas specify their specific prioritisation under consideration of the real-time hydrological conditions, and the defined principles and boundary conditions.

1828 While no order of prioritisation applies to every context, some common principles from current  
 1829 practice and important criteria are collected to guide the allocation process:

1830 **Define the Allocable Pool, accounting for ecological flows**

1831 Central in allocating water, is knowing the allocable pool of the resource throughout the  
 1832 seasons and under changing hydrological conditions, based on updated water balances. The  
 1833 allocable pool is the flow or volume of water available for use in the basin, be it uses that  
 1834 extract and consume water such as drinking water, agriculture and industry, or uses dependent  
 1835 on specific water levels in rivers, lakes and groundwater, such as navigation, hydropower and  
 1836 water tourism. The allocable pool is defined based on hydrological conditions alone (as well  
 1837 as time period). Depending on water demand and the scope of the prioritised water uses in the  
 1838 basin, the “allocable pool” may be above the current demand or may pose a limit to the current  
 1839 demand.

1840 Securing a hydrological regime that maintains ecosystem functioning is a requirement to  
 1841 achieve the environmental objectives specified in Article 4 and Annex VI.2.1 of the WFD. For  
 1842 surface waters, such a hydrological regime shall be captured by the ecological flows, which  
 1843 define water quantities as well as the timing, velocity, and duration of flows or water levels  
 1844 needed to achieve good status. For groundwater bodies, good quantitative status shall be  
 1845 achieved, also considering the groundwater dependencies of ecosystems. This principle should  
 1846 also be kept under drought conditions, whilst Art.4(6) exemptions might be applied e.g. to  
 1847 ensure drinking water supply. Thus, the allocable pool of water only comprises the surplus

1848 (available water resources minus ecological flows). Information on how to determine, ensure  
 1849 and update ecological flows can be found in [Guidance ecological flows](#) (a new one to come in  
 1850 October 2024).

1851 **Safeguard social equity and economic policy considerations**

1852 Existing allocations already place drinking water and critical infrastructure high on the list, in  
 1853 line with Article 16 of the Drinking Water Directive. The former is of course related to the  
 1854 notion of affordable access to drinking water as a human right. Which water use is a priority  
 1855 after that should depend on national, regional or local considerations on social equity and  
 1856 sustainability, as well as some economic criteria. Such priorities shall consider all water uses,  
 1857 not only those who abstract and/or consume water.

1858 A prominent economic factor to consider is the water users' relative need to have assured  
 1859 access to a given stable water supply. Economic agents would be willing to pay to obtain such  
 1860 "allocation rights" but there is currently too little experience with market mechanisms to  
 1861 provide guidance. Many allocation mechanisms try and take account of wider economic  
 1862 stability considerations, trying to prioritise based on avoided jobs and value added. Yet, a  
 1863 rigorous orientation of priority setting based on indicators reflecting economic benefit or jobs  
 1864 per water volume unit may give too little weight to efficiency improvement potential (see  
 1865 below) and the interrelatedness of sectors. In addition, a stable water allocation may degrade  
 1866 into a system of established water rights or set on the basis of political clout.

1867 **Target Efficiency**

1868 In currently existing allocation mechanisms, efficiency is not discussed. How efficiently water  
 1869 is used, however, affects the amount that can be allocated during scarcity. The principle 'water  
 1870 efficiency first', with its origins in the 2012 [Water Blueprint](#), can thus be useful to consider.  
 1871 Water allocation priority could, for example, always come with the requirement to achieve  
 1872 established water leakage levels (e.g. in accordance with [Art. 4\(3\) DWD](#)) to reduce water  
 1873 abstraction for a given consumption level. Further, the WFD under Art 9(1) requires that water-  
 1874 pricing policies, alone or in combination with other policy instruments, provide adequate  
 1875 incentives to use water resources efficiently.

1876 **Maintain flexibility**

1877 Important in the effectiveness of the allocation mechanism is the level at which certain  
 1878 priorities are defined. As a rule, the higher the number of priorities and the more detailed the  
 1879 priority setting, the lesser the remaining flexibility. Another factor with a negative relation to  
 1880 flexibility concerns the time and costs involved in reviewing and adapting the allocation  
 1881 decisions, including legal contestation.

1882 Like in the Belgium-Flanders example, it can be most suitable to define certain priorities on a  
 1883 MS level to ensure compliance with the most relevant environmental and societal needs but  
 1884 leave abundant flexibility at the local/regional level to account for specific contexts and, most  
 1885 importantly, to allow a role for water pricing policies within the given allocated water volume.  
 1886 Both the top-down allocation mechanism and the performance of the lower-level water supply  
 1887 systems should be regularly reevaluated on their functioning and efficiency. This allows also  
 1888 for adaptation to changing hydrological and climatic conditions as needed.

1889 **Involve stakeholders**

1890 Engagement of stakeholders is highly relevant to identify regional needs and gain an overview  
 1891 of the impacts of water scarcity on different users. Stakeholder engagement shall address  
 1892 consumptive as well as non-consumptive uses such as navigation and recreation, as well as  
 1893 other water-related interests. Clarifying allocation priorities can give stakeholders planning  
 1894 security, as they know what to expect under scarcity conditions and can adapt and prepare (e.g.,  
 1895 by adjusting their production processes).

1896 Regarding the process of adapting water allocation regimes to climate change, it is not worthy  
 1897 that most water allocation regimes have grown over decades in a piecemeal fashion, making  
 1898 them rather poorly equipped for smooth adjustments to changing climatic conditions. Water  
 1899 allocation arrangements can be difficult to adjust if they have a high degree of path dependency  
 1900 that manifests itself in both institutional arrangements (law, property rights and policies) and  
 1901 long-lived water infrastructures, such as dams, canals and pipelines. **Adaptation challenges**  
 1902 **for water allocation regimes are further aggravated by the entrenchment of weak water**  
 1903 **policies** (non-respect of Article 9 WFD on pricing of water services; lack of regulating water  
 1904 uses; absence of effective controls of abstraction permits; tolerance of illegal water abstractions  
 1905 etc.), which then exacerbate structural water scarcity (OECD, 2022a).

80. Review and improve the (environmental) water permitting for abstractions, diversions in order to allow for flexible interventions to curb demand ahead of and during a crisis. This requires strong governance structures including monitoring and enforcing abilities.
81. Develop water allocations on the basis of ecological flow regimes and calculations of the water balance at river basin level.
82. Adapt water allocation schemes, taking into consideration climate change impacts and needs for adaptation, based on the OECD Health Check on water allocation mechanisms and CIS-guidance on ecological flows in the implementation of the WFD.
83. Establish a process for reforming (historic) water use rights to reflect changing scarcity and drought conditions and increased risks under climate change.
84. Ensure coordination of water allocation decisions with investments and sectoral policies and support adaptation of water uses to enhance resilience and minimise trade-offs.

1906 **8 NATURE-BASED SOLUTIONS FOR RESILIENCE & CLIMATE**  
 1907 **ADAPTATION**

1908 Nature-based adaptation focuses on ecosystem restoration and the enhancement of ecosystem  
 1909 services to protect society against the negative impacts of climate change, while at the same  
 1910 time increasing ecosystem resilience. Nature-based solutions (NBS) can be considered an  
 1911 'umbrella concept' encompassing a range of established nature-based approaches, which aim to  
 1912 increase resilience to climate change (EEA, 2021a).

1913 There is a broad consensus that NBS deliver multiple benefits, including better water retention  
 1914 capacity, climate change mitigation (mainly through carbon sequestration), biodiversity, water  
 1915 quality and water body conditions, coastal resilience, micro-climate regulation and air quality,  
 1916 and more sustainable communities. The multiple benefits of NBS found in 24 EU-funded  
 1917 projects are bundled in European Commission (2020). NBS bring more, and more diverse,

1918 nature and natural features and processes into cities, landscapes and seascapes, through locally  
 1919 adapted, resource-efficient and systemic interventions. A recent report on the economic  
 1920 rationale of NBS in freshwater ecosystems (Deltares, 2021) illustrates that NBS save costs,  
 1921 contribute to multiple goals at once, often have an attractive socio-economic benefit, and can  
 1922 create jobs. Furthermore, NBS are beneficial for most of the Sustainable Development Goals  
 1923 (SDGs) (Faivre, 2017).

1924 More specifically on water, NBS can substantially contribute to reducing the vulnerability of  
 1925 water management systems by enhancing the water retention capacity and by improving water  
 1926 quality and waterbody conditions. The water retention capacity refers to the natural sponge  
 1927 function of the soil and aquifers so that precipitation is collected, stored and slowly released  
 1928 over time. The capacity to improve water quality refers to the natural treatment and thus  
 1929 cleaning of polluted water, from agricultural and urban stormwater origin. NBS can also  
 1930 enhance hydromorphology and thus improve waterbody conditions. A review of the benefits  
 1931 of NBS for improving water quality and water body conditions, found in EU-funded projects,  
 1932 is published in Wild et al. (2020). The water retention and purification capacity of NBS are  
 1933 important functionalities to better prepare for droughts. Higher storage of better-quality water  
 1934 in natural, often underground water reservoirs results in alternative water access in case of  
 1935 drought.

1936 NBS can be implemented at any scale, from large river restoration projects to small-scale urban  
 1937 infiltration reservoirs and green roofs. Large-scale projects, like Room for the River or some  
 1938 coastal marsh restoration projects, are typically directed to high-risk extreme floods, whereas  
 1939 local scale, often urban NBS, are intended to manage low-risk frequent floods. Some NBS are  
 1940 complemented with grey infrastructure to ensure water safety standards (e.g. reducing pollution  
 1941 of urban runoff before discharge). An overview of the knowledge base on NBS can be found  
 1942 on Climate ADAPT. The EU Guidance document on Natural Water Retention Measures  
 1943 (NWRM) (European Commission, 2014), developed by the CIS Working Group's PoM  
 1944 provides an overview of NWRM, which can be considered as NBS. NWRM include a wide  
 1945 range of measures and can be divided into two broad types.

1946 *Table 3: Illustrating the diversity of measures classified as NWRM (based on European Commission, 2014).*

Type	Class	A non-exhaustive list of examples
Direct modification in ecosystems	Hydro-morphology (River, Lakes, Aquifers, connected wetlands)	Restoration and maintenance of rivers, lakes, aquifers and connected wetlands; Reconnection and restoration of floodplains and disconnected meanders, elimination of riverbank protection; enhancement of the buffering capacity of coastal saltmarshes and intertidal areas.
Change and adaptation in land-use and water management practice	Agriculture	Restoration and maintenance of meadows, pastures, buffer strips and shelter belts, soil conservation practices (crop rotation, intercropping, conservation tillage...), green cover, mulching and agroforestry.
	Forestry and Pastures	Afforestation of upstream catchments, targeted planting for "catching" precipitation; Continuous cover forestry; maintenance of riparian buffers; urban forests; Land-use conversion for water quality improvements and, drainage prevention

	Urban development	Green roofs, rainwater harvesting, permeable paving, swales, soak aways, infiltration trenches, rain gardens, detention basins, retention ponds, urban channel restoration and, sustainable urban drainage systems.
--	-------------------	---

1947

1948 

## 8.1 Costs and benefits

1949 The assessment of costs and benefits and monetising them is particularly complex in the case  
 1950 of NBS. For example, compared to the relative simplicity of calibrating the cost of building a  
 1951 new reservoir and allocating the regulated volumes to various objectives (flood protection and  
 1952 water available for specific users and the environment), there is the complexity of  
 1953 approximating the benefits and distributing the costs of a package of NBS with a similar  
 1954 expected contribution in terms of water availability and flood protection.

1955 It is generally acknowledged that investing in NBS has a sound economic rationale to address  
 1956 flood and drought risks. The World Bank (2021) found that the benefits of flood investments  
 1957 that integrate NBS and early warning had the greatest benefits of all types of investments in  
 1958 disaster risk reduction. Using the Triple Dividend of Resilience Framework, the World Bank  
 1959 calculated very clear benefits of NBS for flood risk management in Europe with a median  
 1960 benefit-cost ratio of almost 5.

1961 Even if the number of economic analyses comparing NBS with conventional alternatives in a  
 1962 river management context is limited, some available studies demonstrate that NBS can be  
 1963 economically attractive. To build a case for green solutions from a water balance improvement  
 1964 perspective, it is necessary to identify and quantify co-benefits as well, integrating their  
 1965 adaptive, multi-purpose and sustainable character so that the favourable impacts are appraised  
 1966 on an appropriate spatial and temporal scale (van Wesenbeeck et al., 2021). NBS often provide  
 1967 multiple co-benefits next to a primary objective, that can be of high relevance in overall and  
 1968 integrated management strategies. Many NBS are characterised by being adaptive to change as  
 1969 ecosystems can adapt to slowly altering conditions over time. For example, sedimentation in  
 1970 salt marshes can enable long-term adaptation to sea level rise, if enough sediment input is  
 1971 available for the sediment's vertical growth. Large-scale ecosystem restoration provides more  
 1972 resilient buffers to climatic instabilities using a catchment approach to flood management for  
 1973 NBS. It can also contribute to better resilience towards droughts and improve biodiversity in  
 1974 the conservation area (Penning, 2022).

*Example 16: Aarhus River enabling infrastructure including real-time control systems*

[FP7 DESSIN's case study](#) of the Aarhus River daylighting reports that enable infrastructure including real-time control systems costs ~€47 million with operating costs of ~600.000/year. The benefits of opening the river and resulting water quality improvements were calculated at €120 million. However, this valuation is limited to the benefit of opening the river in the central city and does not include the social benefits of water quality improvements to the lake, harbour and upper river between the lake and city centre.

1975

*Example 17: CBA of NBS in Italy*

[Liquete et al. \(2016\)](#) report that NBS for water pollution control at Gorla Maggiore, Italy, performed equally or better than the alternative grey infrastructure for water purification and flood protection. Having a similar cost, the ‘end of pipe’ constructed wetlands to treat wastewater from combined sewer overflows, together with the surrounding park – provide additional benefits, including wildlife habitats and recreational opportunities.

1976 The background document for CIS WG Floods provides recommendations on the use of  
1977 economic methods for NBS for flood risk management (Cools & Interwies, 2023).

85. Scan both grey and NBS flood risk measures for their environmental and socio-economic long-term trade-offs. These trade-offs could align with the forthcoming scanning that is needed for a sustainable investment label, or in other words, to become EU taxonomy aligned.
86. Demonstrate the multiple benefits of NBS, in comparison to their costs, as part of the FRMPs and RBMPs, but also as standalone investment cases. Ideally, a cost-benefit analysis or multi-criteria approach is to be used.

## 1978 8.2 Implementation challenges

1979 The evaluation of the first FRMP (European Commission, 2019a) found that NBS are included  
1980 in most plans, with various levels of ambition and specification. Yet, the dominance of grey  
1981 infrastructure for flood risk management remains.

1982 Despite the policy support for NBS, the multi-benefits of NBS for various EU policies,  
1983 including the WFD and FD, and despite the increasing number of relevant projects, the gap for  
1984 implementing NBS seems to remain large (and the implementation is often only at pilot scale).  
1985 Causes for the limited prioritisation and implementation of NBS include:

- 1986 i. The insufficient demonstration of their multiple benefits (in relation to their cost), makes a  
1987 comparison to other (e.g. grey) alternatives difficult.
- 1988 ii. The insufficient understanding of the benefits of NBS given the range of flood return periods.  
1989 It is perceived that NBS are seldom sufficient to provide protection against high-risk extreme  
1990 floods. The need to complement NBS with grey infrastructure can be a way forward.
- 1991 iii. Insufficient scanning of the environmental and socio-economic trade-offs of conventional flood  
1992 risk management measures.
- 1993 iv. The use of social discount rates that give no or very low weight to long-term consequences.  
1994 Many NBS have high initial costs but deliver long-term benefits.
- 1995 v. Higher need for land adjacent to water bodies, which is scarce and costly to acquire. NBS need  
1996 to be implemented on both public and private land. Investments in private land require  
1997 negotiations with landowners.
- 1998 vi. Limited information on the efficiency and climate robustness of NBS measures for the  
1999 resilience of ecosystems against climate change, as the base for selection/prioritisation of NBS.  
2000 Engineers’ acquaintance and long-term experience with grey infrastructure.
- 2001 vii. Limited awareness of best practices due to a lack of institutional guidance.
- 2002 viii. Limited mobilisation of finances and arguments about high maintenance costs.

2003 The potential impacts of climate change on NBS have not been adequately addressed in the  
2004 literature so far (Seddon, et al., 2019). Like other ecosystems, NBS will also be affected by the  
2005 impacts of a changing climate (Gómez, Máñez, & Máñez, 2020). It is known that changes in  
2006 mean air and water temperatures, species distribution or precipitation patterns are highly likely

2007 to alter ecosystem functions and, thus, their ability to meet GES/GEP as well as NBS  
 2008 functionality. The long-term capability of NBS to deal with extreme weather events (such as  
 2009 droughts) may not be sufficient in a climate change context. Additionally, a significant part of  
 2010 the NBS research has been contextualised in cities. Usually, the urban-centred evidence on  
 2011 NBS effectiveness cannot be transferred to rural contexts (Gómez, et al., 2021).

87. Develop and implement practical design and implementation codes (standardisation codes) for NBS to help grey infrastructure engineers to also include NBS into their projects, while also offering guidance to ecosystem restoration workers.

88. Systematically examine NBS alternatives when rebuilding after a natural disaster (i.e. flood).

89. Develop standardised methods to calculate the costs and benefits of NBS.

90. Mobilise and combine financial resources, better use existing financial flows for NBS and/or blend finances of various sources for a common action plan on NBS.

91. Create Natural Water Reserves in the most water-stressed areas and apply NBS to protect and restore freshwater sources and the catchment areas in those reserves. Make those Natural Water reserves part of the water infrastructure, so that they can benefit from funding traditionally earmarked to infrastructure spending and make the protection and restoration of those Natural Water Resources of overriding public interest.

2012

### 2013 8.3 NBS supporting the implementation of WFD and FD

2014 NBS can improve or preserve hydro-morphological conditions, coastal resilience, as well as  
 2015 water quantity and quality. A review of the multiple benefits of NBS has been recently released  
 2016 (European Commission, 2020a), together with another one, specifically reviewing the value of  
 2017 NBS for water quality and hydro-morphology (European Commission, 2020). The latter  
 2018 provides an analysis of EU-funded projects and includes a section on combined sewer  
 2019 overflows, and other water quality-related aspects of floods.

2020 The FD states the FRMPs shall consider ‘...areas which have the potential to retain flood water,  
 2021 such as natural floodplains...’ and that they may include the ‘...improvement of water  
 2022 retention...’ (Article 7(3)). In the preamble, the FD asks FRMPs to ‘consider where possible  
 2023 the maintenance and/or restoration of floodplains...’. The reporting guidance on the FD refers  
 2024 to NBS under ‘measure type M31: Protection natural flood management/runoff and catchment  
 2025 management’. Measure M31 is defined as ‘Measures to reduce the flow into natural or artificial  
 2026 drainage systems, such as overland flow interceptors and/or storage, enhancement of  
 2027 infiltration, etc. and including in-channel, floodplain works and the reforestation of banks, that  
 2028 restore natural systems to help slow flow and store water.’

#### *Example 18: NBS supporting the implementation of WFD and FD in the Netherlands*

The Ruimte voor de Rivier IJsseldelta project in the Netherlands is part of the national programme "Ruimte voor de Rivier" and includes 34 measures to improve the safety and aesthetics of Dutch river areas. The project aims to address water safety and contributes to various aspects such as economic development, public transportation, housing, nature conservation, agriculture, tourism, and water recreation. The results of the project include a water-secure and climate-resilient region, a new high-water channel named Reevediep, enhanced infrastructure, and the creation of new delta nature and bird habitats.

2029

*Example 19: NBS to reduce hydro-meteorological risks in rural and mountainous regions.*

[H2020 PHUSICOS](#) investigates the use of NBS to reduce hydro-meteorological risks in rural and mountainous regions. The project delivers a ‘receded green barrier’ on the River Gausa, at Jorekstad near Lillehammer, Norway. Built using only natural and local materials, the barrier will contribute to water quality improvements to meet WFD objectives. Due to diffuse pollution impacts from agricultural land runoff, the river has only moderate ecological status with regard to total phosphorous, and a poor state in terms of total nitrogen. By creating a wetland and setting back the flood barrier the scheme is intended to prevent plastics and other substances from entering the river, as well as reducing nitrogen and phosphorous runoff, and mitigating the loss of fish habitats and spawning areas.

#### 2030 8.4 NBS and droughts

2031 Flood risk mitigation-oriented NBS have usually secondary positive effects on resilience to  
2032 droughts, as they increase natural water holding capacity. This is relevant as the number of  
2033 NBS approaches targeting primarily floods is significantly larger than those targeting droughts  
2034 (Sahani et al., 2019).

2035 However, there are also NBS targeting specific droughts and water scarcity; for example, the  
2036 prevention of and clearing of invasive alien trees has shown positive effects on drought-  
2037 impacted streamflow (Holden et al., 2022). The installation of watering points can reduce  
2038 wildlife losses during droughts (Sahani et al., 2019). Riparian trees are known to reduce water  
2039 temperatures (Trimmel, et al., 2018). Furthermore, conservation agriculture, i.e. using  
2040 combined methods of improved cultivation on arable land, has proven to be effective in  
2041 reducing water stress by changing soil infiltration parameters (reducing bulk density and  
2042 increasing organic matter) (Burek, et al., 2012).

2043 More knowledge is however still needed on the long-term benefits of NBS. There is still low  
2044 evidence, including the applicability of NBS to manage highly vulnerable ecosystems and in  
2045 agriculture (IPCC, 2022).

*Example 20: Co-creating ‘healthy green corridor NBS’ with citizens*

[H2020 URBINAT](#) is co-creating a ‘healthy green corridor NBS’ with citizens in seven EU cities. At Porto in Portugal, this process includes the active participation of parish organisations and initiatives to involve local actors, resources and talents in designing and creating interventions. Also in Portugal, a €75m [national programme](#) has been commissioned to restore 5,000 km of freshwater streams, using NBS to help prevent forest fires, soil erosion, droughts and flooding, and to improve biodiversity and water quality. Within this programme, 1,000km length of rivers have already been restored (costing €11.5m) and a further 5,000km are targeted for restoration (costs €75m). The Minister of the Environment has highlighted that such NBS are part of the national effort to reduce emissions and mitigate against climate change and that NBS living labs in 16 different municipalities helped bring together civil engineers, local authorities, the forestry sector, and other businesses. Riverside ‘parkways’ connecting urban and rural communities represent important opportunities to achieve synergies between ecosystem restoration and social integration.

## 2046 9 CROSS-BORDER/TRANSBOUNDARY ASPECTS OF CLIMATE 2047 ADAPTATION

2048 Overexploitation and pollution of lakes, rivers, and aquifers can jeopardise ecosystem services  
2049 across borders, but can also have negative impacts on certain economic sectors (e.g. agriculture  
2050 or waterborne transport). Coastal resources can be jeopardised by upstream activities as  
2051 depleted aquifers can allow saltwater intrusion in coastal areas and increase the concentration  
2052 of arsenic fluoride and other toxic substances in ground waters needed by consumers and  
2053 industry. A unilateral move by one country to build a dam could drastically reduce a river's  
2054 flow downstream in another country. These transboundary aspects gain even more momentum  
2055 under climate change.

2056 Water management and adaptation within a transboundary basin are challenging and require  
2057 strong cooperation between the riparian countries at different levels and with the water-related  
2058 sectors, institutions, and other stakeholders with often conflicting and competing interests and  
2059 needs. At the same time, transboundary cooperation can bring multiple benefits and make  
2060 adaptation more efficient by sharing data, enlarging the planning scale, selecting better  
2061 adaptation priorities, avoiding negative impacts of unilateral measures (maladaptation) as well  
2062 as sharing costs and benefits. In addition, it also supports sustainable development and regional  
2063 integration (UNECE, 2009). The European region is quite advanced in transboundary  
2064 cooperation in climate change adaptation. For example, basins such as the Danube, the  
2065 Dniester, the Neman and the Rhine have developed and implemented transboundary adaptation  
2066 strategies and plans. Others, such as the Drin, the Meuse and the Sava integrate climate change  
2067 issues while developing their RBM and FRMP (WMO, 2021).

2068 A transboundary approach adds the requirements for MS to pool available data, models,  
2069 scenarios and resources together to plan and adopt actions (UNECE & INBO, 2015). The  
2070 common collection and exchange of information is an essential basis needed to develop an  
2071 effective transboundary ecosystem-based climate change adaptation strategy. Joint or  
2072 harmonised impact assessments, monitoring, and information systems such as databases or GIS  
2073 systems are the key to eliminate conflicting results and policies (Rieu-Clarke, et al., 2015). The  
2074 WFD and the FD both contain provisions for transboundary management and mainstreaming  
2075 climate adaptation measures in a transboundary context:

- 2076 • The **WFD** encourages MS to implement common principles to coordinate the efforts in the  
2077 protection of water bodies and sustainable water use in terms of transboundary water problems  
2078 (Preamble 35). MS shall ensure to assign affected river basins to an international river basin  
2079 district and implement monitoring systems comparable to the community in order to develop  
2080 programmes fitting to the objectives. Furthermore, there is the possibility for MSs to request  
2081 the Commission to facilitate the establishment of the programmes of measures (Article 2  
2082 ((4&5)) (EU, 2000).
- 2083 • The **FD** points out, that effective flood prevention and mitigation requires coordination between  
2084 MS or third countries (Preamble 6). For transboundary rivers that means the development of  
2085 FRMPs should not include measures which increase flood risks upstream or downstream of  
2086 other countries unless these had been negotiated this way (Article 7((4)). Therefore, in a

2087 transboundary context, MSs should coordinate to agree to a single or a set of common FRMPs  
 2088 (Article 8 ((2)) (EU, 2007).

2089 To strengthen and simplify the cooperation between MS, this guidance document provides a  
 2090 short listing of good practices, which should be considered for a successful cooperation  
 2091 between riparian countries.

## 2092 **Preparing the ground for a transboundary cooperation**

2093 The process starts usually with the collaboration between the involved ministers of the riparian  
 2094 countries and the institutions responsible for the coordination, which ideally leads to an  
 2095 international cooperation body. Afterwards, the collaboration should be extended to other  
 2096 stakeholders. The aim is to bring climate experts, hydrology and ecology experts and political  
 2097 leaders together to support the development of an accurate picture of adaptation challenges and  
 2098 possible solutions at a transnational but also regional level. The first step in developing a  
 2099 common strategy or adaptation planning is usually a study on the climate change vulnerability  
 2100 of the river basin or region (Mekong River Commission [MRC], 2014). Besides setting up the  
 2101 process in a structured way, gathering first information, an estimation of human and financial  
 2102 resources is needed and the identification of potential sources for long-term funding should be  
 2103 made (Climate ADAPT, 2023a). The main factors determining the duration until the adaptation  
 2104 of the strategy are the availability of information and the extend of the mandate (e.g. a detailed  
 2105 versus a more generic strategy) (MRC, 2014).

## 2106 **Water diplomacy**

2107 Water diplomacy can be defined as the use of diplomatic instruments to existing or emerging  
 2108 disagreements and conflicts over international shared water resources with the aim to solve or  
 2109 mitigate those for the sake of cooperation, regional stability, and peace. Diplomatic instruments  
 2110 may include negotiations, dispute-resolution mechanisms, the establishment of consultation  
 2111 platforms, and the organisation of joint fact-finding missions. Technical instruments - such as  
 2112 establishing basin-wide management plans or joint monitoring networks - are not part of water  
 2113 diplomacy. While diplomatic and technical instruments often build on each other and can be  
 2114 directly linked, consistently defining water diplomacy merits this strict differentiation as will  
 2115 become clear later on (Schmeier, 2018). The Global Water Partnership provides a [Toolbox](#) for  
 2116 Integrated Water Resource Management including a tool about water diplomacy, that explains  
 2117 several tracks that can be used in water diplomacy and introduces regional and basin dialogue  
 2118 pathways for water diplomacy.

### *Example 21: The Albufeira Convention between Spain and Portugal*

The [Albufeira Convention](#), signed in 1998, is the legal instrument that articulates the cooperation mechanisms between Spain and Portugal for the protection of surface and groundwater and the aquatic and terrestrial ecosystems directly dependent on them, as well as for the sustainable use of the water resources of the Spanish-Portuguese hydrographic basins. There are five river basins shared between Spain and Portugal (Minho, Lima, Douro, Tagus and Guadiana), integrated in four international RBDs. The shared basins occupy 46% of the territory of the Iberian Peninsula - 64% of Portugal and 42% of Spain. This agreement culminates a long history of establishing partnerships and treaties regarding those rivers

dating back to the 19th century, mostly to define boundaries and uses of the rivers' bordering stretches. The Convention was revised in 2008 to reinforce the sustainable water management, according to the WFD. The Albufeira Convention addresses new challenges arising from the WFD and the current state of shared basins, including water quality and resource availability during drought periods. In practice, beyond the formal structures, the Convention's cooperation mechanisms are based on a regular and systematic exchange of information, consultations and activities within the Technical Secretariats and the Convention, and the people engaged in the working groups, and the adoption of technical measures in a spirit of good cooperation.

## 2119 **Development of data exchange mechanisms**

2120 The next step includes the development of new applications of existing mechanisms to  
 2121 exchange information between the involved countries. This includes the standardisation of  
 2122 already used but also of newly collected data like impact assessments, monitoring or  
 2123 information systems to guarantee efficient cooperation (UNECE & INBO, 2015). A successful  
 2124 approach to exchange data is also a way to reduce costs.

### *Example 22: Data and information sharing*

[International Meuse Commission \(IMC\)](#) was established in 2002 with the objective of achieving sustainable and integrated water management of the international Meuse River basin. The agreement was signed by the Walloon Region, the Netherlands, France, Germany, the Flemish Region, the Brussels-Capital Region, Belgium, and Luxembourg, and it came into effect on December 1, 2006. Therefore, a coordination platform was established to ensure the transmission of necessary information like the implementation of protection measures against and the prevention of the negative effects of floods and droughts.

## 2125 **Management of the international river basins**

2126 For successful cooperation on climate change adaptation within a river basin, appropriate  
 2127 institutional arrangements and principles of integrated water resource management are  
 2128 necessary. Therefore, a framework like a transboundary agreement is an important mechanism  
 2129 for solving disputes and can support the development and implementation of adaptation  
 2130 strategies and measures. A good example is provided by the river basin of the Danube. The  
 2131 Danube cooperation area stretches from Germany crossing 14 states up to the estuary in  
 2132 Romania. The cooperation includes a set of common policy frameworks like the Danube  
 2133 RBMP, the Danube Flood Risk Management Plan and the Strategy on adaptation to Climate  
 2134 Change. The latter includes guidance on the integration of climate change adaptation processes,  
 2135 and the promotion of multilateral and transboundary cooperation action and serves as a  
 2136 reference for national policymakers and other officials (Climate ADAPT, 2023a).

2137 Besides a common agreement, the implementation of a basin organisation to get a coordinated  
 2138 overview of the activities and formulate the strategy is essential. The organisations should  
 2139 harmonise tools, methods, models and scenarios to be used and to prepare a basin-wide  
 2140 assessment in a good way. Useful initiatives include the establishment of dedicated working  
 2141 groups on adaptation or integrating adaptation into other relevant working groups within a  
 2142 transboundary organisation. On the content level, it is important to include experts from all

2143 riparian countries to have a diverse input of knowledge (UNECE & INBO, 2015). Although  
2144 transboundary agreements and organisations play a crucial role in climate change adaptation,  
2145 transboundary basins, where such agreements and organisations are not in place yet, can  
2146 establish less formal mechanisms of transboundary cooperation to develop, coordinate and  
2147 implement adaptation strategies. Such more technical cooperation can even result in broader  
2148 and more formal transboundary cooperation. For example, in the Dniester basin shared by  
2149 Moldova and Ukraine, joint activities on transboundary climate change adaptation (namely the  
2150 development of the joint adaptation strategy and its implementation plan) facilitated the entry  
2151 into force of the transboundary agreement and establishment of the dedicated Commission  
2152 (UNEP, 2021). Following a gendered balance approach through evidence-based policies  
2153 informed by gender-disaggregated data, the inclusion of a gender perspective in the  
2154 consultation and decision-making process, and the promotion of gender-sensitive beneficiary  
2155 groups in the management is recommended (Rieu-Clarke, et al., 2015).

### 2156 **Methods and tools used**

2157 Climate change effects are just one of the pressures, other pressures do exist (economic,  
2158 demographic, etc.) (UNECE & INBO, 2015). A useful tool to rate climate-related impacts or  
2159 other pressures and develop procedures for analysing adaptation options or strategies can be  
2160 the application of a Multi-criteria analysis. In order to gain an accurate picture of the successful  
2161 performance of the measures a Monitoring, Reporting and Evaluation (MRE) system using an  
2162 approach combining quantitative and qualitative methods is needed to support the process. This  
2163 allows robust, consistent and contextualised analyses of the performance of the implemented  
2164 measures (Climate ADAPT, 2023a). As a good practice example, the cooperation of the  
2165 Danube Basin developed a platform called '[Climate Change Adaptation Measures Toolbox](#)'  
2166 where possible adaptation measures are provided and categorised in different fields and types.

### 2167 **Implementing the adaptation plan or strategy**

2168 The adaptation plan or strategy sets out what needs to be done to convert options into actions,  
2169 specifying roles, responsibilities, timing, and addressing resource needs and allocation. It  
2170 guides the process by providing a detailed roadmap for putting measures into practice  
2171 (Climate ADAPT, 2023a). To raise the effectiveness and reduce the occurrence of physical or  
2172 institutional barriers, the implementation of the adaptation plan or strategy should be adopted  
2173 with other relevant policies. The acceptance and compatibility with other policies as well as  
2174 river basin and FRMP is important to ensure appropriate funding and the realisation of at least  
2175 a part of the strategy measures. A framework can serve as a conflict prevention tool between  
2176 riparian countries, by addressing national legal weaknesses and establishing a fair playing field  
2177 for weaker and stronger neighbours by setting minimum substantives and procedural rules to  
2178 be followed (Rieu-Clarke, et al., 2015). To avoid future conflicts the existence of a strong  
2179 policy framework in times of climate change will become even more important because the  
2180 more frequent occurrence of extreme events (e.g. droughts) will evoke challenges like the  
2181 possible default of water delivery agreements between basin countries.

2182 The implementation of measures should be prioritised where the entire basin can benefit from.  
2183 For instance, if an upstream country takes flood reduction measures, the downstream country

2184 may benefit from this or if a downstream country expands its waterway the upstream country  
 2185 may be granted access and benefit as well. Therefore, it is useful to cooperate and share benefits  
 2186 and costs between riparian countries to improve efficiency (UNECE, 2020). However, issues,  
 2187 social costs or the transfer of vulnerability within the basin to another location should be  
 2188 avoided. Measures with low or no regret potential should be realised at the beginning, while  
 2189 the assessments on the scenarios and uncertainty trajectories are still running. It is moreover  
 2190 important to rely the risk management on local knowledge and not necessarily implement  
 2191 instruments blindly (Rieu-Clarke, et al., 2015).

92. Ensure a cross-sectoral approach when selecting adaptation actions including the transboundary level, in order to prevent possible conflicts between different sectors and to consider trade-offs and synergies between adaptation and mitigation measures.
93. When planning adaptation across boundaries, focus on preventing negative transboundary impacts, sharing benefits and risks equitably and reasonably and cooperating based on equality and reciprocity.
94. Ensure that data and information related to water availability, water characterisation and water needs, including that from early warning systems, is shared between countries and sectors as this is essential for effective and efficient climate change adaptation across transboundary basins. Make policy coordination truly operational via international agreement, if possible.
95. Enable the sharing of costs (and benefits, as mentioned above) for climate adaptation measures, taking into account the risk entailed on each side.
96. Give more attention to direct and indirect socio-economic effects at border areas (e.g. lost/new jobs, change in utilities, etc)
97. Bolster enforcement community at the transboundary level (building on enforcement trust relationship)

2192

## 2193 10 HOW TO DO A CLIMATE CHECK OF MEASURES (ADAPTATION 2194 AND MITIGATION)?

2195 The overall aim of the climate check is to ensure that the water management measures  
 2196 stipulated in RBM and FRM plans are sufficiently adaptive to future climate conditions. It  
 2197 could contain two main steps that address two different levels: the PoM level and the individual  
 2198 project level:

- 2199 • Step 1: Screening phase for Key Type Measures (KTMs). The screening phase should provide  
 2200 a form of sensitivity analysis for the selection of measures that are effective, robust and cost-  
 2201 efficient under changing conditions and are in line with RBMP objectives/FRM objectives and  
 2202 climate goals. The selected measures should ensure that the water management objectives are  
 2203 met in a future that is impacted by climate change.  
 2204 Generally, only measures that are robust to climate change impacts and do not contribute to  
 2205 amplifying climate change and its impacts should pass the climate check and should be  
 2206 considered. As RBMP and /or FRM planning involves hundreds of measures it is impossible to  
 2207 check each of them at each location. Therefore, this check is proposed on KTM and sub-KTM  
 2208 levels. The appropriate level needs to be defined by the competent authority.
- 2209 • Step 2: At the implementation stage detailed proofing for single measures in particular for the  
 2210 development of infrastructure projects is done. This process integrates climate proofing with

2211 project cycle management (PCM), environmental impact assessments (EIA), and strategic  
 2212 environmental assessment (SEA) processes following the Commission Notice Technical  
 2213 guidance on the climate proofing of infrastructure in the period 2021-2027 (2021/C 373/01).  
 2214 This is particularly important when measures have a long lifetime and are cost-intensive and  
 2215 when assessing whether these measures are still effective under the likely or possible future  
 2216 climate change scenarios and different adaptation pathways.

### 2217 10.1 Step 1: Screening phase for KTMs and Sub-KTMs at PoM level

2218 The structure of the check to be performed by the competent authority primarily includes two  
 2219 areas ('assessment areas') that are of main relevance: climate robustness and contribution to  
 2220 climate change. Each assessment area is then broken down into several topics which are  
 2221 assessed along a set of questions<sup>32</sup>.

Assessment area	Topic	Short explanation
Climate robustness	Topic 1: Relevance of the measure	It examines the relevance of the measure under changed climatic conditions.
	Topic 2: Effectiveness of the measure	It examines the effectiveness of the measure under changed climatic conditions.
	Topic 3: Flexibility and reversibility of the measure	It examines how flexible the measure is and how it can be adjusted to changed climatic conditions.
	Topic 4: Side effects	It examines if the measure has positive or negative effects on other ecosystems or activities within water management relevant sectors in the future.
Contribution to climate change	Topic 5: Intensification of climate change	It should examine if the measure intensifies climate change, e.g. it leads to a release of additional GHG <sup>33</sup> .

#### 2222 10.1.1 Application: Assessment area 1 'Climate Robustness'

2223 In many areas due to the long-term changes in precipitation regimes, as well as the change in  
 2224 frequency of extreme events caused by climate change, a climate check of measures could be

<sup>32</sup> This approach has been developed by the German Federal Environmental Agency.

<sup>33</sup> During the development of the Screening Tool methodology, it was also discussed how to determine if a measure intensifies climate change impacts. Due to the complexity of the causation between climate change - measure - effect and the difficulties in the assessment, this aspect was not included. In addition, taking into account the WFD principle of preventing any deterioration in status, no measures may be taken that worsen the condition of a body of water. This also applies to changing climatic conditions.

2225 included in the WFD management plans, DMP and the FRMP and would be an important task  
2226 for public administrations.

2227 The first assessment area determines the **climate robustness** of a water management measure  
2228 under changing climatic conditions based on different criteria.

### 2229 **Topic 1: Relevance of the measure**

2230 Information for the assessment of the following question should be included in the chapter  
2231 dealing with the aspect of ‘Future Developments’ of the RBMP.

2232 **How does the relevance of the measure change regarding the water management**  
2233 **objective taking into account the (previously identified) climate consequences?**

2234 **Description:** The question about the relevance of a measure assumes that certain water  
2235 management measures completely lose their relevance in the future – once the projected future  
2236 climate changes occur – or could gain relevance concerning the water management objectives.  
2237 This needs to be particularly considered to reach GES/GEP or the set flood management  
2238 objectives.

2239 **Example:** There will be increased erosion and higher concentrations of nutrients in waterways  
2240 caused by more frequent and intense rain events. Measures like riparian buffer strips are  
2241 therefore even more relevant in the future. The same applies to measures dealing with flood  
2242 protection/flood risk management. The dimensions/designs of overflow basins for rainwater  
2243 regarding increased and/or heavier rain have to be reconsidered because their relevance would  
2244 increase in such a case.

2245 **Assessment scheme:** A separate assessment must be carried out for each identified change in  
2246 the climate hazard system (drought, flood, heavy rain, low water levels, storm surges, changes  
2247 in the groundwater level/recharge including groundwater flooding, as well as air and water  
2248 temperature increases).

Relevance strongly decreases			Relevance does not change			Relevance strongly increases
-3	-2	-1	0	+1	+2	+3

### 2249 **Topic 2: Effectiveness of the measure**

2250 This Topic is assessed based on multiple questions:

2251 **Does climate change alter the effectiveness of the measure regarding the water**  
2252 **management objective?**

2253 **Description:** This question determines if the effectiveness of a measure changes with respect  
2254 to the water management goal under the projected climatic changes.

2255 **Example:** Due to higher air temperatures in the future, the cleaning performance of sewage  
2256 treatment plants will increase (i.e. their effectiveness increases – greater loads will be treated).

2257 **Assessment scheme:** A separate assessment should be carried out for each identified change  
2258 in the climate system.

Effectiveness strongly decreases			Effectiveness does not change			Effectiveness strongly increases
-3	-2	-1	0	+1	+2	+3

2259

2260 **How do the maintenance costs of the measure change due to the projected climate**  
2261 **change impacts?**

2262 **Description:** This question should be used to examine the changing operating costs, i.e. the  
2263 costs of maintenance of the measure.

2264 **Example:** Based on more frequent or stronger flood events, the costs for preservation and  
2265 maintenance of flood protection measures or the costs to maintain water infrastructures that  
2266 will transport less water due to a lower water level may increase. Increased drainage, however,  
2267 may also lead to stronger sediment transport and increased shore erosion and therefore cause  
2268 increased costs in river maintenance.

2269 **Assessment scheme:**

Costs strongly increase			Costs do not change			Costs strongly decrease
-3	-2	-1	0	+1	+2	+3

2270 **Topic 3: Flexibility and reversibility of the measure**

2271 **How far can the measures be adjusted/modified in case of more frequent and intense**  
2272 **extreme events (including quick changes between different events (e.g. droughts and**  
2273 **floods)?**

2274 **Description:** This question examines if the measure can be adjusted to changes in the climate  
2275 system such as the more frequent occurrence of drought and floods and the close occurrence  
2276 of both after each other. This is geared towards the ‘technical’ adjustment or modification of  
2277 an existing measure at a later point in time.

2278 **Example:** Low flexibility means that a measure may only be adjusted with very high expenses  
2279 or costs (for example, ‘costs for the adjustment’ correspond to the ‘costs for construction’ of  
2280 the measure). With medium flexibility, the measures may be adjusted under certain  
2281 prerequisites, for example, the increase in the height of dikes or the construction of additional  
2282 retention areas for flood management. On the other side, high flexibility occurs where measures  
2283 can be adjusted without considerable costs, like for certain measures in mobile flood protection  
2284 or early warning systems.

2285 **Assessment scheme:**

Only adjustable with very high expenses						High flexibility
-3	-2	-1	0	+1	+2	+3

2286

2287

2288

**Does the measure have installed/planned safety margins that guarantee the function of the measure regarding its water management goal under changing climate?**

2289

2290

2291

**Description:** The question examines if during the planning/design of the measure, the expected climatic changes were considered by integrating safety margins and therefore the water management objective of the measure can be reached with higher probability.

2292

2293

2294

**Example:** During the assessment of flood protection measures, a factor for climate change was considered. Flood design discharge has been increased beyond the statistically determined data (e.g. HQ100).

2295

**Assessment scheme:**

Safety margins not present	Safety margins are not important for the measure	Safety margins present
-3	0	+3

2296

2297

2298

**Is the measure also reasonable if climate change does not develop as given by currently available climate projections (so-called ‘no-regret’ or ‘low-regret’ measures)?**

2299

2300

2301

**Description:** The question examines if the measure should be considered reasonable despite climate projections do not pan out, i.e. if the measure is reasonable independent of climate change (so-called ‘no-regret’ or ‘low-regret’ measures).

2302

2303

2304

2305

2306

2307

**Example:** Examples of low and no regret measures are the existing limitation of new construction in areas at risk of flooding (because these are in a risk zone independent of climate change) or the creation of protected areas/natural retention areas (because these also help to achieve biodiversity goals). Other examples of low/no-regret measures include the reduction of leakage in the water infrastructure or all measures that lead to a decrease in water demand (see attachment).

2308

**Assessment scheme:**

No low-regret/no-regret measure	Low-regret/no-regret measure
0	+3

2309

**Topic 4: Side effects and co-benefits**

2310

2311

**Does the measure improve/worsen the resilience of ecosystems compared to the projected climate change impacts?**

2312

2313

**Description:** This question examines if the measure improves or worsens the resilience of ecosystems against climate change compared to the projected climate change impacts.

2314

2315

2316

**Example:** Climate change and its consequences may have effects on the functionality of ecosystems, for example through a change in water and temperature/other physico-chemical regimes. This may result in changes of the species composition. A water management measure

2317 may strengthen or weaken the resilience of affected ecosystems; thus, a measure that increases  
 2318 the temperature of waterways (e.g. wastewater flows into water courses with increasingly low  
 2319 water) would lead to worsening resilience of the surrounding ecosystems. The opposite applies  
 2320 to a measure that increases the water quantity available (e.g. through savings). Measures that  
 2321 lower the flow of hazardous substances and nutrients into ecosystems (like riparian buffer strips  
 2322 or the expansion of treatment plants) increase their resilience.

2323 **Assessment scheme:**

Strongly reduces resilience			Resilience does not change			Strongly increases resilience
-3	-2	-1	0	+1	+2	+3

2324

2325 **Is this measure optimising its potential to support adaptation objectives?**

2326 **Description:** To foster synergies of water and climate adaptation, it is not only necessary to  
 2327 look at the conformity of reaching objectives (and not to amplify climate change – see  
 2328 assessment area 2), but also to design planned measures in such a manner that it achieves the  
 2329 intended objective while optimising its potential to support climate protection and adaptation  
 2330 objectives or to bring other co-benefits.

2331 **Example:** The restoration of an urban river stretch to improve hydromorphology could also be  
 2332 carried out in a way that reduces urban heat island effects.

2333 **Assessment scheme:**

Maladaptation if the measure is possible/given	No support for climate change adaptation	High support for adaptation to climate change
-3	0	+3

2334

2335 **Is this measure coherent with an existing climate adaptation strategy in place at a high**  
 2336 **governmental level?**

2337 **Description:** A central question for the assessment of measures is their coherence with a  
 2338 possibly existing climate adaptation strategy (e.g. at the national level). The selected measures  
 2339 should ideally agree with such a strategy.

2340 **Example:** The creation of natural retention areas for floods and nature protection on  
 2341 agricultural land represents, for example, a conflict of use. This measure is considered coherent  
 2342 with a climate adaptation strategy, for example at the national level, if the strategy calls for the  
 2343 expansion of natural retention spaces.

2344 **Assessment scheme:**

No coherence with adaptation strategies at a high governmental level	No information / no high-level adaptation plan	High coherence with adaptation strategies at a high governmental level
--	---	--

-3	0	+3
----	---	----

2345

## 2346 10.1.2 Application: Assessment area 2 'Effects on climate change'

2347 This second assessment area deals with undesired feedback of the measure contributing to  
2348 amplifying climate change and its impacts.

2349 **Topic 5: Intensification of climate change**

2350 **Does the implementation of the measure lead to the direct emission of greenhouse gases**  
2351 **(GHG)?**

2352 **Description:** Many water management measures (for example under the management plans of  
2353 the WFD and the FD) can amplify climate change by, e.g., directly releasing GHG throughout  
2354 their lifespan.

2355 **Example:** Wastewater treatment plants without gas caps directly emit methane during  
2356 operation. On the other side, the reforestation or restoration of wetlands (e.g. for flood  
2357 protection) may permanently absorb and retain carbon dioxide (CO<sub>2</sub>-reduction).

2358 **Assessment scheme:**

High GHG emissions	Medium GHG emissions	No/low GHG emissions	Medium CO <sub>2</sub> -reduction	High CO <sub>2</sub> -reduction
-3	-2	0	+2 (e.g. wet meadows)	+3 (e.g. peatlands)

2359

2360 **How high is the energy consumption of the measure during its operation (indirect**  
2361 **contribution to climate change)?**

2362 **Description:** This question examines the energy consumption of the measure or its  
2363 maintenance during its operation and corresponds to its indirect contribution to the emission of  
2364 greenhouse gases.

2365 **Example:** When answering the question, the entire lifespan of the measure should be  
2366 considered. If the measure consumes significant quantities of energy, it should be evaluated as  
2367 a generally high greenhouse gas emission.

2368 **Assessment scheme:**

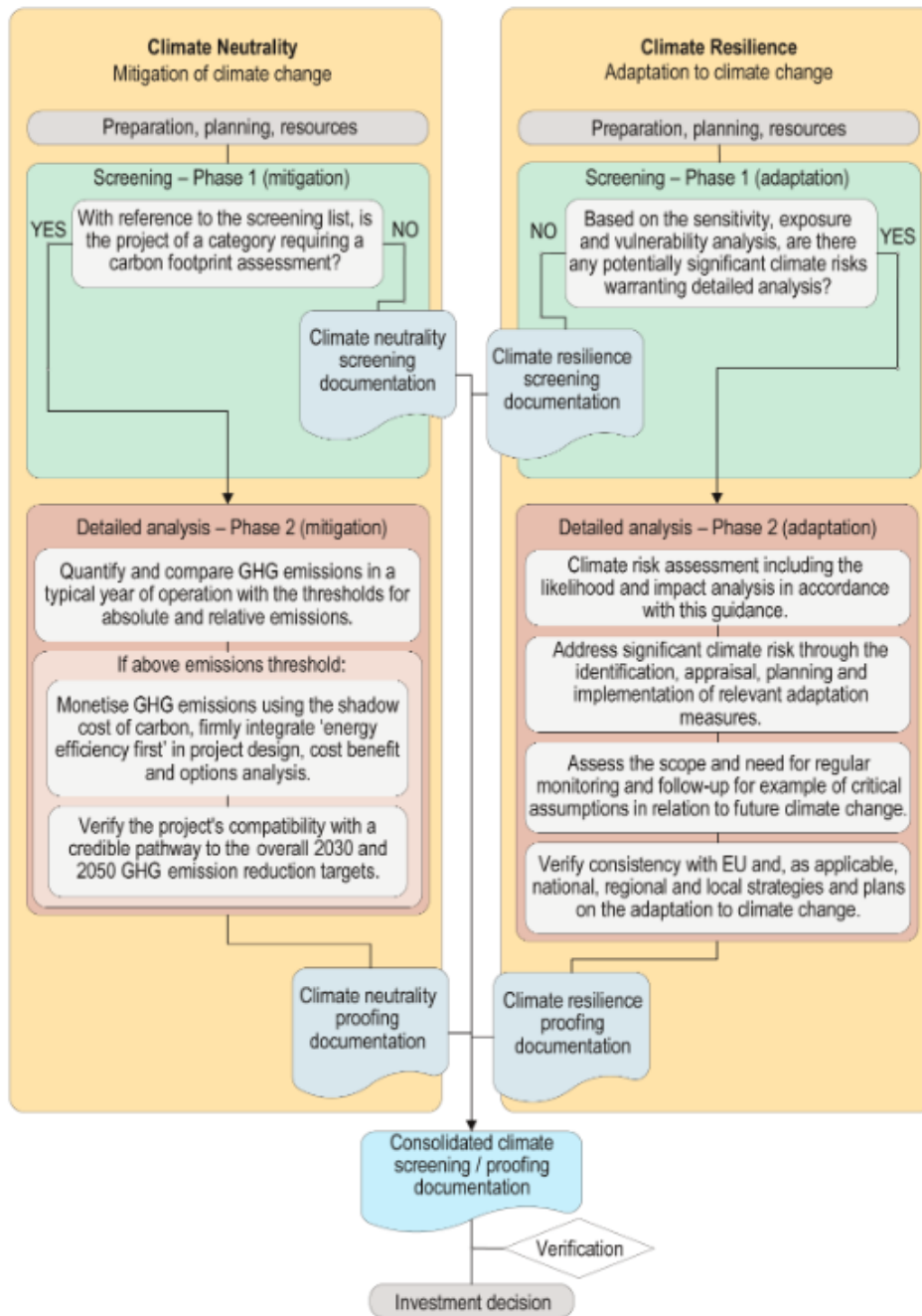
High energy consumption during operation	Medium energy consumption during operation	No/low energy consumption during operation
-3	-2	0

2369

## 2370 10.2 Step 2 Detailed proofing of infrastructure projects

2371 Climate proofing on the project level integrates climate change mitigation and adaptation  
2372 aspects into the development of infrastructure projects when implementing measures set out in  
2373 the RBMPs. The Guidance document understands infrastructure as a broad concept addressing  
2374 different type like buildings, nature-based infrastructure, network infrastructure, systems to  
2375 manage waste, or other physical assets. However, it makes sense to carry out detailed reviews,  
2376 especially for larger infrastructure projects with a long lifespan, high investment costs, and  
2377 impact on the environment in order to limit the bureaucratic effort.

2378 The process of climate proofing is integrated into project cycle management (PCM),  
2379 environmental impact assessments (EIA), and strategic environmental assessment (SEA)  
2380 processes and follows the ‘[Technical guidance on the climate proofing of infrastructure in the  
2381 period 2021-2027’ of the Commission](#)’. It enables users to make informed decisions on  
2382 projects that qualify as compatible with the Paris Agreement and EU climate objectives, which  
2383 means it is consistent with a credible GHG emission reduction pathway in line with the EU’s  
2384 new climate targets for 2030 and climate neutrality by 2050, as well as with climate-resilient  
2385 development. The application of the guidance is mandatory for European projects falling under  
2386 the Common Provisions Regulation as well as under the Recovery and Resilience Facility.  
2387 There are two pillars (mitigation and adaptation) and two phases (screening and detailed  
2388 analysis), which are illustrated in the following figure and after further detailed (European  
2389 Commission, 2021).



2390

2391 *Figure 7: Climate proofing and the pillars on 'climate neutrality' and 'climate resilience' (European Commission, 2021).*2392 **10.2.1 Climate Neutrality – Mitigation of climate change**2393 **Preparation, planning and resources:**

2394 An early-stage and consistent assessment of expected greenhouse gas emissions over the many  
 2395 development stages of a project helps to mitigate its impact on climate change. There is a range  
 2396 of choices that can be made during the planning and design stages that may affect the project's  
 2397 GHG emissions over its lifespan, from construction and operation until decommissioning. In  
 2398 certain sectors (e.g. transport, energy and urban development), it is mainly at the planning level  
 2399 that effective actions must be taken to reduce GHG.

2400 **Screening – Phase 1 (mitigation):**

2401 In the first phase, the project should be examined with respect to the mandatory/optional carbon  
 2402 footprint assessment. Such an assessment is required, e.g., for heavy industry, power plants,  
 2403 and landfills. Whereas, it is not required for telecommunication service, drinking- and  
 2404 rainwater supply networks.

- 2405 • If the project does not require a carbon footprint assessment, summarise the analysis in a climate  
 2406 neutrality screening statement, which in principle (funding-specific requirements on, e.g. the  
 2407 cost-benefit analysis may include GHG emissions) gives a conclusion on climate proofing with  
 2408 regard to climate neutrality.
- 2409 • If the project requires a carbon footprint assessment, proceed to phase 2.

2410 **Detailed analysis – Phase 2 (mitigation):**

2411 If this phase is mandatory, quantify GHG emissions in a typical year of operation using the  
 2412 carbon footprint method. It is recommended to use, where applicable, the EIB carbon footprint  
 2413 methodology (to quantify GHG emissions) and the EIB shadow cost of the carbon method (to  
 2414 monetise GHG emissions). Then they should be compared with the thresholds for absolute and  
 2415 relative GHG emissions (threshold >20.000 tonnes CO<sub>2</sub>e/year [positive or negative]). If the  
 2416 GHG emissions exceed any of these thresholds, carry out the following analysis:

- 2417 • Monetise GHG emissions using the shadow cost of carbon (a continuous increase from 80 euros  
 2418 in 2020 to 800 euros in 2050 per ton) and then integrate the ‘energy efficiency first’ principle<sup>34</sup>  
 2419 in the project design, options analysis, and the cost-benefit analysis.
- 2420 • Verify the project’s compatibility with a credible pathway to achieve the overall 2030 and 2050  
 2421 GHG emission reduction targets. For infrastructure with a lifespan beyond 2050, the project’s  
 2422 compatibility with operation, maintenance and final decommissioning under conditions of  
 2423 climate neutrality should be acknowledged.

2424 **10.2.2 Climate Resilience – Adapting to climate change**

2425 **Preparation, planning and resources:**

2426 Infrastructure is usually long-lasting and may be exposed to a changing climate for many years  
 2427 with increasingly adverse and frequent extreme weather and climatic impacts. It is  
 2428 recommended to integrate the climate vulnerability and risk assessment from the beginning of  
 2429 the project development process, including EIA because this will generally provide the  
 2430 broadest range of possibilities for selecting the optimal adaptation options. For example, the  
 2431 project location, which is often decided at an early stage, can be decisive for a climate change  
 2432 vulnerability and risk assessment. There will usually be more constraints when the assessment  
 2433 is initiated later in the project development, which could lead to suboptimal solutions being  
 2434 chosen. In addition to factoring in the climate resilience of the project, there must be measures  
 2435 to ensure that the project does not increase the vulnerability of neighbouring economic and  
 2436 social structures. This could happen, for instance, if a project includes an embankment that  
 2437 could increase flood risk in the vicinity.

2438 **Screening – Phase 1 (adaptation):**

---

<sup>34</sup> Emphasises the need to prioritise alternative cost-efficient energy efficiency measures when making investment decisions, in particular cost-effective end-use energy savings.

2439 The first step is to carry out a climate **sensitivity** (ranking of the relevant climate variables and  
 2440 hazards for a given project type), **exposure** (ranking of the relevant climate variables and  
 2441 hazards for the selected location) and **vulnerability** (summarises the sensitivity and exposure  
 2442 analysis) **analysis**:

2443 • If there are no significant climate risks warranting for a further analysis, compile the documentation  
 2444 and summarise the analysis in a climate resilience screening statement, which in principle gives a  
 2445 conclusion on climate proofing with regard to climate resilience.

2446 • If there are significant climate risks warranting for a further analysis, proceed to phase 2 below.

2447 **Detailed analysis – Phase 2 (adaptation):**

2448 The next step is to carry out a **likelihood** (summarises likelihood of climate variables and  
 2449 hazards in a qualitative or quantitative way) and **impact** (potential impact of the climate  
 2450 variables and hazards) **analysis** which is concluded in the climate **risk assessment** (detailed  
 2451 summary of likelihood and impact analysis, including the explanation and quantification of  
 2452 risk levels):

2453 • Address significant climate risks by identifying, appraising, planning and implementing  
 2454 relevant and suitable adaptation measures.

2455 • Assess the scope and need for regular monitoring and follow-up, for example, critical  
 2456 assumptions in relation to future climate change.

2457 • Verify consistency with the EU and, as applicable, national, regional and local strategies and  
 2458 plans on the adaptation to climate change, and other relevant strategic and planning documents.

2459 The documentation and the analysis should be summarised in the climate resilience proofing  
 2460 statement, that gives a conclusion on climate proofing with regard to climate resilience on  
 2461 which the decision is made.

98. Perform a climate check of the water management plans and programmes to:

- a. Ensure Climate Resilience: Climate proofing helps water management programmes become more resilient, capable of adapting to these changes and minimising risks associated with unpredictable and severe weather conditions.
- b. Protect Water Resources: By climate-proofing water management, these programmes can better protect and preserve water sources, ensuring sustainable access to clean water for various purposes, including drinking, agriculture, and industry.
- c. Mitigate Risks of Flooding and Drought: Climate-proofing allows water management programmes to prepare for and mitigate the risks associated with both flooding and drought.
- d. Preserve Ecosystems: A robust climate-proofing strategy in water management helps to protect ecosystems that rely on water bodies. Maintaining an ecological balance ensures the safeguarding of biodiversity, which, in turn, supports various ecosystem services crucial for human well-being.
- e. Improve Infrastructure Planning and Maintenance: Climate-proofing helps in planning, constructing, and maintaining water infrastructure that can withstand changing climatic conditions, reducing the vulnerability of water-related structures

to extreme weather events and rising sea levels. It also helps to ensure that costly investments will also work in the future.

2463 **11 ANNEX I: ADAPTATION ACTIONS/MEASURES – SOURCES OF**  
 2464 **INFORMATION**

2465 **11.1 General measures**

2466 Climate change is affecting water management in different ways. Therefore, the EU provides  
 2467 and supports several information tools for MS where they can get and exchange information  
 2468 and good practice examples.

Name	Description
<a href="#">WISE</a>	The Water Information System for Europe (WISE) provides information and resources to adapt water resources to climate change.
<a href="#">Climate-ADAPT</a>	The website aims to support Europe in adapting to climate change and provides information and tools that can be used to adapt states, regions, urban and rural areas to tackle water-related issues.
<a href="#">NWRM</a>	The Natural Water Retention Measures promotes actions that aim to protect and manage water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes.
<a href="#">DRYvER</a>	The project aims at developing strategies to mitigate and adapt to climate change effects in drying river networks, integrating hydrological, ecological (including NbS), socio-economic and policy perspectives.
<a href="#">EFAS</a>	The Copernicus European Flood Awareness System (EFAS) provides probabilistic flood alert information more than 48 hours in advance, which is used by emergency managers across Europe.
<a href="#">EDO</a>	The Copernicus European Drought Observatory provides drought-relevant information and predictions
<a href="#">LISFLOOD</a>	The LISFLOOD model, developed by the JRC of the European Commission, is a hydrological rainfall-runoff model capable of simulating the hydrological processes that occur in a catchment.

2469

2470 The EU published a series of reports concerning water-related topics.

2471 i. [European climate risk assessment](#)

2472 The EUCRA report builds on and complements the existing knowledge base on climate  
 2473 impacts and risks for Europe, including recent reports by the Intergovernmental Panel on  
 2474 Climate Change, the Copernicus Climate Change Service and the Joint Research Centre of the  
 2475 European Commission, as well as outcomes of EU-funded research and development projects  
 2476 and national climate risk assessments.

2477 ii. [Climate change impacts and adaptation in Europe](#)

2478 The report includes several chapters related to water resources, concluding that droughts will  
 2479 happen more frequently, last longer and become more intense, especially in southern and  
 2480 western parts of Europe. Furthermore, river and coastal floods are likely to increase.

- 2481 [iii. Climate change and Europe’s water resources](#)  
 2482 The report delivers projections of future water resources, due to climate change, land use  
 2483 change and changes in water consumption.
- 2484 [iv. Global warming and drought impacts in the EU](#)  
 2485 The report concerns the more frequent occurrence of droughts and their increasing intensity.  
 2486 Furthermore, it estimates the annual economic loss in different climate change scenarios.
- 2487 [v. Global warming and human impacts of heat and cold extremes in the EU](#)  
 2488 The report addresses the rising frequency of heatwaves and the resulting damage it causes  
 2489 economically but also leads to rising mortality due to these extreme conditions within citizens.
- 2490 [vi. Adapting to rising coastal flood risk in the EU under climate change](#)  
 2491 The report concerns the adaptation measures that could be taken to mitigate and lower the  
 2492 damage caused by sea level rise in coastal areas.
- 2493 [vii. Adapting to rising river flood risk in the EU under climate change](#)  
 2494 The report addresses the growing flood risk in river basins due to climate change and how  
 2495 building-based damage reduction measures and the reduction of flood peaks using retention  
 2496 areas can be implemented to lower the impacts in a cost-efficient way.
- 2497 [viii. Quantitative and qualitative aspects of water safety under a changing climate](#)  
 2498 The report addresses the critical nexus between drinking water availability and various factors  
 2499 affecting freshwater, including extreme weather events and slow-onset climate changes. It  
 2500 conducts a rapid review and qualitative rating of issues such as urban land cover, agricultural  
 2501 activities, water storage, water abstraction, and infrastructure, identifying them as key  
 2502 contributors to medium-high risks of climate change impact, with water abstraction posing the  
 2503 highest risk.

2504

## 2505 11.2 Urban measures

2506 European cities are already facing a number of climatic disasters (e.g. heat waves, river  
 2507 floodings, pluvial floods, and water scarcity). Due to the ongoing climate change and the  
 2508 intensification and frequency of extreme events, cities need to identify their vulnerability to  
 2509 these hazards and adapt their adaptive capacity accordingly. To support urban areas in the  
 2510 implementation of measures there are resources provided with good practice examples on how  
 2511 to adapt.

Name	Description
<a href="#">SCOREwater</a>	The project aims to introduce digital services to improve the management of wastewater, stormwater and flooding events to enhance the resilience of cities against climate change.
<a href="#">Urban Storm</a>	The LIFE project facilitates the development and implementation of integrated approaches for climate change adaptation strategies and action plans to increase the climate resilience of Estonian municipalities, especially their ability to manage flash flooding.

<a href="#">SPONGE 2020</a>	The project produced a toolbox, a guidance package and a cross-border action plan to support stakeholder engagement and participative actions in climate change adaptation to better manage urban flooding.
-----------------------------	---

2512

2513 

### 11.3 Rural measures

2514 Rural areas in the EU are sensitive to changes in the water balance. A change in water  
 2515 availability affects not only the local inhabitants, who are dependent on resilient water  
 2516 resources but also the ecosystems. Climate change is leading to an increase in heavy rain and  
 2517 longer drought events, which lead to a rising problem of water scarcity, crop failures, forest  
 2518 fires, floods and pressure on biodiversity. Therefore, water-related resources for a better  
 2519 understanding and good practice examples are provided.

Name	Description
<a href="#">RECONNECT</a>	The project aims to rapidly enhance the European reference framework on NbS for hydro-meteorological risk reduction by demonstrating, referencing, upscaling and exploiting large-scale NbS in rural and natural areas.
<a href="#">OPERANDUM</a>	The project works on the reduction of hydro-meteorological risks in European territories through co-designed, co-developed, deployed, tested and demonstrated innovative green and blue/grey/hybrid NbS.

2520

## 2521 12 ANNEX II EXAMPLES OF THE IMPACT OF CLIMATE CHANGE ON 2522 THE QUALITY ELEMENTS

2523 *Example 23: Increasing brownification of lakes in Northern Europe: Lake Bolmen in Sweden, moving from low to high colour.*

2524 *Water Category: Lakes*

2525 *BQE methods: Phytoplankton, Macrophytes*

2526 Climate change in combination with less acid rain and changes in catchment vegetation have caused  
 2527 brownification of lakes in particular in northern Europe (Finstad et al., 2016). This increased flux of  
 2528 humic substances into rivers and lakes, as well as to downstream estuaries and coastal waters can alter  
 2529 aquatic geochemistry and light climate. This impacts the structure and functioning of aquatic systems,  
 2530 for example altering phytoplankton composition, sometimes increasing nuisance species such as  
 2531 *Gonyostomum semen* or leading to a reduction of benthic macrophytes such as isoetids and favouring  
 2532 species that can grow taller in the water column such as elodids (Mormul et al., 2012; Kritzberg et al.,  
 2533 2020). This has important implications for WFD assessment, as the humic state is used in the type  
 2534 description for rivers and lakes in the Northern inter-calibration group as well as the Baltic Sea.

*Example 24: The Italian deep subalpine lakes - cascading effects from increased winter temperatures, reduced mixing and altered nutrient dynamics.*

*Water Category: Alpine Lakes*

*BQE methods: Italian Phytoplankton Assessment Method (IPAM), BQIES (Benthic Quality Index Expected Species number)*

The deep subalpine lakes are of key economic importance in northern Italy and their size and depth make them a key regional water resource requiring priority management (Premazzi et al., 2003; Regione del Veneto, 2018). A warming trend has been detected in the lakes with annual average surface temperatures increasing by  $0.017\text{ }^{\circ}\text{C yr}^{-1}$  and  $0.032\text{ }^{\circ}\text{C yr}^{-1}$  in summer (Pareeth et al., 2017). This has led to more stable stratification and increasing isolation of the hypolimnion from the epilimnion, altering nutrient dynamics, with no complete mixing since 2006. This has led to a gradual decrease in oxygen concentrations in the hypolimnion with the result that climate now exerts more control on oxygen than trophic status (Rogora et al., 2018). This, in turn, has also reduced nutrient transfer from the hypolimnion to the epilimnion resulting in alterations to phytoplankton composition (Salmaso et al., 2018).

While in some cases, chlorophyll-a may decline with continued stratification, superficially indicating an improvement, the composition of the phytoplankton community may change or other biological quality elements such as macroinvertebrates in the sub-littoral and profundal zones may deteriorate given the lower oxygen concentrations below the thermocline (Rossaro et al., 2007). An issue of future concern is a possible mixing event that may deliver to the surface layer water with low oxygen and high nutrients. Quantifying the relative role of altered stratification, nutrient loading and their interaction for diverse BQEs remains a challenge. Climate change may therefore create pressure to alter management targets and strategies as the lake typology (e.g. typology system B: mixing characteristics) and, therefore, ecological status boundaries may effectively change, presenting a stark choice between setting unobtainable goals and the need to protect and improve water quality (Cardoso et al., 2009).

2535

*Example 25: Science challenge – Developing an approach that maintains the integrity of the WFD assessment system in a changing climate.*

Further research, including modelling, is needed to develop and test other approaches based on an understanding of climate change effects in a multi-pressure context. One possibility is the establishment of a subscript value to an EQR<sup>35</sup> to quantify the decrease in EQR estimated as attributable to climate change. For example, a reported EQR of **0.55<sub>0.10</sub>** would indicate that established assessment systems have assigned an EQR of **0.55** (moderate status) but the subscript of **0.10** indicates that climate change is responsible for a decline of 0.10 (from 0.65 to 0.55) resulting in a change from good to moderate status. Essentially this would be conceptually similar to temperature anomaly maps where deviation from the established normal conditions is reported.

Such a system could be applied by MS to their waterbodies where the EQR is being modified by climate change. Supporting information regarding the climate extremes experienced by a site can be taken from annual European State of the [Climate reports](#) that provide data and maps on temperature anomaly, soil moisture deficit, river discharge and associated documents on heatwaves and floods. However, **attributing a portion of an EQR decline to climate change will be a key scientific challenge**. Approaches could include model development or more simple comparisons with years

<sup>35</sup> Ecological Quality Ratio (EQR) incorporates the key WFD requirements for ecological classification: typology, reference conditions, and class boundary setting.

where the climate was more representative of normal conditions (for example identified from published maps of monthly temperature anomaly).

Further work is needed, including how to manage objectives and Programmes of Measures in this context – would the component of the EQR attributable to climate change be subject to additional measures if feasible (e.g. reducing nutrients further) or could it be used to allocate or manage exemptions/derogations? Several benefits are also apparent:

- i. Maintains original EQR (for time-series analysis)
- ii. Makes transparent the MS estimate of how CC is influencing the waterbody
- iii. There should be broad consistency for regions/types, allowing us to understand how CC is affecting aquatic ecology across Europe.

In some respects, the WFD is already complex and adding another layer is regrettable. However if MS seek to modify their objectives by citing the effect of climate change, the presentation of two pieces of evidence for the waterbody is inevitable: 1) evidence of deteriorating climate and 2) an estimation of how much of the status decline is due to climate change and no other factors.

2536

### 2537 13 ANNEX III: ROLE OF THE SEA AND EIA PROCESS IN CLIMATE 2538 CHANGE ADAPTATION

2539 A Strategic Environmental Assessment (SEA) is a systematic process for evaluating the  
2540 environmental implications of a proposed policy, plan or programme and provides means for  
2541 looking at cumulative effects and appropriately addressing them at the earliest stage of  
2542 decision-making alongside economic and social considerations. The SEA assesses the extent  
2543 to which a given policy, plan or programme:

- 2544 • provides an adequate response to environmental and climate change-related challenges;
- 2545 • may adversely affect the environment and climate resilience, and
- 2546 • offers opportunities to enhance the state of the environment and contribute to climate-resilient  
2547 and low-carbon development.

2548 Ideally, a SEA should be integrated into the policy, plan or programme preparation process  
2549 from its early stages and the Government must have a high degree of ownership. Public  
2550 participation is also essential for a successful SEA.

2551 In 2013 the EC developed [guidance](#) on Integrating Climate Change and Biodiversity into  
2552 Strategic Environmental Assessment to improve the consideration of these issues across the  
2553 EU MSs.

2554 The Environmental Impact Assessment (EIA) Directive requires MSs to ensure that projects  
2555 likely to have significant effects on the environment because of their nature, size or location  
2556 are subject to an assessment of their environmental effects. This assessment should take place  
2557 before development consent is given, i.e. before the authority/ies decides (s) that the developer  
2558 can go ahead with the project.

2559 The Directive harmonises EIA principles by introducing minimum requirements, in particular  
2560 for the types of projects that should be assessed, the main obligations of developers, the  
2561 assessment's content and provisions on the participation of competent authorities and the  
2562 public.

2563 The [Guidance](#) on Integrating Climate Change and Biodiversity into Environmental Impact  
 2564 Assessment aims to help MSs improve how climate change and biodiversity are integrated in  
 2565 EIAs carried out across the EU.

2566 In cases where structural measures such as dams or weirs are needed to mitigate droughts and  
 2567 floods Art 4.7. WFD might be applied. In such a case the links between WFD, EIA and SEA  
 2568 should be considered. The relevance and potentials for synergies and streamlining of  
 2569 assessments required under the EIA and Article 4(7) are specified in more detail in [Guidance](#)  
 2570 [No. 36](#) - Article 4(7) exemptions to the environmental objectives (see in particular chapter 4.2  
 2571 and Annex A).

## 2572 14 GLOSSARY

2573 **Adaptation:** In human systems, the process of adjustment to actual or expected climate and its  
 2574 effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the  
 2575 process of adjustment to actual climate and its effects; human intervention may facilitate  
 2576 adjustment to expected climate and its effects.

2577 **Adaptive capacity:** The ability of systems, institutions, humans and other organisms to adjust  
 2578 to potential damage, to take advantage of opportunities, or to respond to consequences. This  
 2579 glossary entry builds from definitions used in previous IPCC reports and the Millennium  
 2580 Ecosystem Assessment.

2581 **Aridity:** The state of a long-term climatic feature characterised by low average precipitation  
 2582 or available water in a region. Aridity generally arises from widespread persistent atmospheric  
 2583 subsidence or anticyclonic conditions, and from more localised subsidence in the lee side of  
 2584 mountains.

2585 **Climate Change:** A change in the state of the climate that can be identified (e.g., by using  
 2586 statistical tests) by changes in the mean and/or the variability of its properties and that persists  
 2587 for an extended period, typically decades or longer. Climate change may be due to natural  
 2588 internal processes or external forcings such as modulations of the solar cycles, volcanic  
 2589 eruptions and persistent anthropogenic changes in the composition of the atmosphere or in  
 2590 land-use.

2591 **Cost–benefit analysis:** Monetary assessment of all negative and positive impacts associated  
 2592 with a given action. Cost–benefit analysis enables the comparison of different interventions,  
 2593 investments or strategies and reveals how a given investment or policy effort pays off for a  
 2594 particular person, company or country. Cost–benefit analyses representing society’s point of  
 2595 view are important for climate change decision-making, but there are difficulties in aggregating  
 2596 costs and benefits across different actors and across timescales.

2597 **Drought:** Drought is a natural phenomenon. It is a temporary, negative and severe deviation  
 2598 along a significant time period and over a large region from average precipitation values (a  
 2599 rainfall deficit), which might lead to meteorological, agricultural, hydrological and  
 2600 socioeconomic drought, depending on its severity and duration.

2601 **Ecological Flows:** Ecological flows (often abbreviated as e-flows) are considered within the  
2602 context of the WFD as “a hydrological regime consistent with the achievement of the  
2603 environmental objectives of the WFD in natural surface water bodies as mentioned in Article  
2604 4(1)”. Considering Article 4(1) WFD, the environmental objectives refer to: (a) non  
2605 deterioration of the existing status (b) achievement of good ecological status in a natural surface  
2606 water body, (c) compliance with standards and objectives for protected areas, including the  
2607 ones designated for the protection of habitats and species where the maintenance or  
2608 improvement of the status of water is an important factor for their protection, including relevant  
2609 Natura 2000 sites designated under the Birds and Habitats Directives (BHD). Where water  
2610 bodies can be designated as heavily modified water bodies and/or qualify for an exemption,  
2611 related requirements in terms of flow regime are to be derived taking into account technical  
2612 feasibility and socio-economic impacts on the use that would be impacted by the  
2613 implementation of ecological flows. The flow to be implemented in these water bodies is not  
2614 covered by the working definition of ecological flows and it will be named distinctively.

2615 **Ecosystem services:** Ecological processes or functions having monetary or non-monetary  
2616 value to individuals or society at large. These are frequently classified as (1) supporting  
2617 services such as productivity or biodiversity maintenance, (2) provisioning services such as  
2618 food or fibre, (3) regulating services such as climate regulation or carbon sequestration, and (4)  
2619 cultural services such as tourism or spiritual and aesthetic appreciation.

2620 **Emission scenario:** A plausible representation of the future development of emissions of  
2621 substances that are radiatively active (e.g., GHGs, aerosols) based on a coherent and internally  
2622 consistent set of assumptions about driving forces (such as demographic and socio-economic  
2623 development, technological change, energy and land use) and their key relationships.  
2624 Concentration scenarios, derived from emissions scenarios, are often used as input to a climate  
2625 model to compute climate projections.

2626 **Extreme weather event:** An event that is rare at a particular place and time of year. Definitions  
2627 of ‘rare’ vary, but an extreme weather event would normally be as rare as or rarer than the 10<sup>th</sup>  
2628 or 90<sup>th</sup> percentile of a probability density function estimated from observations. By definition,  
2629 the characteristics of what is called extreme weather may vary from place to place in an  
2630 absolute sense.

2631 **Flood:** The overflowing of the normal confines of a stream or other body of water, or the  
2632 accumulation of water over areas that are not normally submerged. Floods include river  
2633 (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, and  
2634 glacial lake outburst floods.

2635 **Forecasts:** Prediction (with included uncertainty/error) of the future based on the current  
2636 conditions and past events, factors and trends.

2637 **Governance:** A comprehensive and inclusive concept of the full range of means for deciding,  
2638 managing, implementing and monitoring policies and measures. Whereas government is  
2639 defined strictly in terms of the nation-state, the more inclusive concept of governance  
2640 recognises the contributions of various levels of government (global, international, regional,

2641 sub-national and local) and the contributing roles of the private sector, of nongovernmental  
2642 actors, and civil society to addressing the many types of issues facing the global community.

2643 **Hazard:** The potential occurrence of a natural or human-induced physical event or trend that  
2644 may cause loss of life, injury, or other health impacts, as well as damage and loss to property,  
2645 infrastructure, livelihoods, service provision, ecosystems and environmental resources.

2646 **Maladaptation:** Actions that may lead to an increased risk of adverse climate-related  
2647 outcomes, including via increased GHG emissions, increased vulnerability to climate change,  
2648 or diminished welfare, now or in the future. Maladaptation is usually an unintended  
2649 consequence.

2650 **Mitigation (of climate change):** A human intervention to reduce emissions or enhance the  
2651 sinks of greenhouse gases. Note that this encompasses carbon dioxide removal (CDR) options.

2652 **Mitigation measures:** In climate policy, mitigation measures are technologies, processes or  
2653 practices that contribute to mitigation, for example, renewable energy technologies, waste  
2654 minimisation processes, public transport commuting practices.

2655 **Monitoring and evaluation:** Monitoring and evaluation refers to mechanisms put in place at  
2656 national to local scales to respectively monitor and evaluate efforts to reduce GHG and/or adapt  
2657 to the impacts of climate change with the aim of systematically identifying, characterising and  
2658 assessing progress over time.

2659 **Projections:** Potential future evolution of a quantity or set of quantities characterising the earth  
2660 system, often computed with the aid of a model. Unlike predictions, projections are not  
2661 initialised with current climate conditions but rely on observed forcing (e.g. in terms of  
2662 emissions) and on scenarios of future socio-economic and technological developments that  
2663 may or may not be realised.

2664 **Resilience:** The capacity of interconnected social, economic and ecological systems to cope  
2665 with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain  
2666 their essential function, identity and structure. Resilience is a positive attribute when it  
2667 maintains capacity for adaptation, learning and/or transformation.

2668 **Risk Reduction:** Three components of risk (hazard, exposure, vulnerability) must be described  
2669 in terms that are sector, location, and dynamic specific (Harm, Wolters, Timboe, & Matthews,  
2670 2022). Adaptation can reduce the risk by addressing one or more of the three risk factors. The  
2671 reduction of vulnerability, exposure, and/or hazard potential can be achieved through different  
2672 policies and actions over time until limits to adaptation are reached.

2673 **Scenarios:** A plausible description of how the future may develop based on a coherent and  
2674 internally consistent set of assumptions about key driving forces (e.g., rate of technological  
2675 change, prices) and relationships. Note that scenarios are neither predictions nor forecasts but  
2676 are used to provide a view of the implications of developments and actions.

2677 **Water abstraction:** Water is removed from any sources, either permanently or temporarily.  
2678 Mine water and drainage are included. Similar to water withdrawal.

2679 **Water body:** Any mass of water having definite hydrological, physical, chemical and  
2680 biological characteristics and which can be employed for one or several purposes.

2681 **Water demand:** Water demand is defined as the volume of water requested by users to satisfy  
2682 their needs. In a simplified way it is often considered equal to water abstraction, although  
2683 conceptually the two terms do not have the same meaning.

2684 **Water pollution:** Presence in water of harmful and objectionable material - obtained from  
2685 sewers, industrial wastes and rainwater run-off - in sufficient concentrations to make it unfit  
2686 for use.

2687 **Water resources:** Distinction is made between renewable and non-renewable water resources.  
2688 Non-renewable water resources are not replenished at all or for a very long time by nature. This  
2689 includes the so-called fossil waters. Renewable water resources are rechargeable due to the  
2690 hydrological cycle unless they are overexploited, comprising groundwater aquifers and surface  
2691 water like rivers and lakes. Internal renewable water resources comprise the average annual  
2692 flow of rivers and groundwater generated from endogenous precipitation.

2693 **Water reuse:** Reclaimed water can be indirectly reused when it is discharged into a  
2694 watercourse, diluted and used again downstream. Direct reuse means the direct supply of  
2695 reclaimed water from the reclamation facility to the user. It also can apply to the recharge of  
2696 an aquifer.

2697 **Water scarcity:** Water scarcity is a man-made phenomenon. It is a recurrent imbalance that  
2698 arises from an overuse of water resources, caused by consumption being significantly higher  
2699 than the natural renewable availability. Water scarcity can be aggravated by water pollution  
2700 (reducing the suitability for different water uses), and during drought episodes.

2701 **Water stress:** Water stress occurs when the demand for water exceeds the available amount  
2702 during a certain period or when poor quality restricts its use. Water stress causes deterioration  
2703 of freshwater resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and  
2704 quality (eutrophication, organic matter pollution, saline intrusion, etc.).

2705 **Water supply:** Water supply refers to the share of water abstraction which is supplied to users  
2706 (excluding losses in storage, conveyance and distribution).

2707 **Water use:** Three types of water use are distinguished: (i) withdrawal, where water is taken  
2708 from a river, or surface or underground reservoir, and after use returned to a natural water body,  
2709 e.g. water used for cooling in industrial processes. Such return flows are particularly important  
2710 for downstream users in the case of water taken from rivers; (ii) consumptive, which starts with  
2711 withdrawal but in this case without any return, e.g. irrigation, steam escaping into the  
2712 atmosphere, water contained in final products, i.e. it is no longer available directly for  
2713 subsequent uses; (iii) non-withdrawal, i.e. the in situ use of a water body for navigation  
2714 (including the floating of logs by the lumber industry), fishing, recreation, effluent disposal  
2715 and hydroelectric power generation.

2716 **15 References**

- 2717 Abdellatif, et al. (2015). Quantitative assessment of sewer overflow performance with climate  
2718 change in northwest England. *Hydrological Sciences Journal*, 60, 636-650.  
2719 doi:10.1080/02626667.2014.912755
- 2720 Asmala, E., Carstensen, J., Raike, & A. (2019). *Multiple anthropogenic drivers behind upward*  
2721 *trends in organic carbon concentrations in boreal rivers*. IOP Publishing Ltd.  
2722 doi:10.1088/1748-9326/ab4fa9
- 2723 Athanasiou, P., van Dongeren, A., Giardino, A., Vousdoukas, M., Ranasinghe, R., & Kwadijk,  
2724 J. (2020). *Uncertainties in projections of sandy beach erosion due to sea level rise: an*  
2725 *analysis at the European scale*. *Sci Rep* 10, 11895. doi: [https://doi.org/10.1038/s41598-](https://doi.org/10.1038/s41598-020-68576-0)  
2726 [020-68576-0](https://doi.org/10.1038/s41598-020-68576-0)
- 2727 Barnett, J., Graham, S., Mortreux, C., Fincher, R., Waters, E., & A., H. (2014). *A local coastal*  
2728 *adaptation pathway*. *Nature Climate Change*. doi:<https://doi.org/10.1038/nclimate2383>
- 2729 BRLi. (2023). *Étude de l'hydrologie du fleuve Rhône sous changement climatique*. Retrieved  
2730 from [https://www.eaurmc.fr/jcms/pro\\_118205/fr/une-etude-sur-les-debits-du-rhone-](https://www.eaurmc.fr/jcms/pro_118205/fr/une-etude-sur-les-debits-du-rhone-pour-anticiper-leur-evolution)  
2731 [pour-anticiper-leur-evolution](https://www.eaurmc.fr/jcms/pro_118205/fr/une-etude-sur-les-debits-du-rhone-pour-anticiper-leur-evolution)
- 2732 Brosse, M., Benateau, S., Gaudard, A., Stamm, C., & Altermatt, F. (2022). The importance of  
2733 indirect effects of climate change adaptations on alpine and pre-alpine freshwater  
2734 systems. doi:<https://doi.org/10.1002/2688-8319.12127>
- 2735 Burek, P., Mubareka, S., Rojas Mujica, R., De Roo, A., Bianchi, A., Baranzelli, C., & Lavallo,  
2736 C. (2012). *Evaluation of the effectiveness of Natural Water Retention Measures -*  
2737 *Support to the EU Blueprint to Safeguard Europe's Waters*. Luxembourg  
2738 (Luxembourg): Publications Office of the European Union. JRC75938.
- 2739 Castellarin, A., Kohnova, S., Gaal, L., Fleig, A., Salinas, J., & Toumazis, A. (2012). *Review of*  
2740 *applied-statistical methods for flood-frequency analysis in Europe*. Centre for Ecology  
2741 and Hydrology.
- 2742 CCNR. (2021). *Act Now! On low water and effects on Rhine navigation*. Central Commission  
2743 for the Navigation of the Rhine. Retrieved from [https://www.ccr-](https://www.ccr-zkr.org/files/documents/workshops/wrshp180123/Act_now_3_0_en.pdf)  
2744 [zkr.org/files/documents/workshops/wrshp180123/Act\\_now\\_3\\_0\\_en.pdf](https://www.ccr-zkr.org/files/documents/workshops/wrshp180123/Act_now_3_0_en.pdf)
- 2745 Climate ADAPT. (2023a). *The Adaptation Support Tool - Getting started*. Retrieved January  
2746 17, 2023, from [https://climate-adapt.eea.europa.eu/en/knowledge/tools/adaptation-](https://climate-adapt.eea.europa.eu/en/knowledge/tools/adaptation-support-tool/step-1-3)  
2747 [support-tool/step-1-3](https://climate-adapt.eea.europa.eu/en/knowledge/tools/adaptation-support-tool/step-1-3)
- 2748 Cools, J., & Interwies, E. (2023). *Cost-benefit assessment for nature-based solutions for flood*  
2749 *mitigation. Developed under the Framework Contract 'Water for the Green Deal' -*  
2750 *Implementation and development of the EU water and marine policies*  
2751 *(09020200/2022/869340/SFRA/ENV.C.1)*. Specific Contract "Support to the  
2752 Commission on water quantity management – follow up to the Fitness Check of EU  
2753 water law conclusions, EU Strategy on Adaptation to Climate Change and Common  
2754 Implementation Strategy Work Programme for the water directives .

- 2755 Cramer, W., Yohe, M., Auffhammer, C., Huggel, U., Molau, M., da Silva Dias, A., . . . Stone,  
2756 a. L. (2014). *Detection and attribution of observed impacts*.
- 2757 Deltares. (2021). *Economic rationale of NBS in freshwater ecosystems*. Deltares.
- 2758 Deltares. (2023). *Dynamic Adaptive Policy Pathways*. Retrieved from  
2759 [https://www.deltares.nl/en/expertise/areas-of-expertise/sea-level-rise/dynamic-](https://www.deltares.nl/en/expertise/areas-of-expertise/sea-level-rise/dynamic-adaptive-policy-pathways)  
2760 [adaptive-policy-pathways](https://www.deltares.nl/en/expertise/areas-of-expertise/sea-level-rise/dynamic-adaptive-policy-pathways)
- 2761 Dorado-Guerra, D. Y., Paredes-Arquiola, J., Pérez-Martín, M. Á., Corzo-Pérez, G., Ríos-  
2762 Rojas, & L. (2023). *Effect of climate change on the water quality of Mediterranean*  
2763 *rivers and alternatives to improve its status*. *Journal of Environmental Management*,  
2764 348, 119069.
- 2765 EEA. (2018). *Water use in Europe - Quantity and quality face big challenges*. Retrieved from  
2766 [https://www.eea.europa.eu/signals/signals-2018-content-list/articles/water-use-in-](https://www.eea.europa.eu/signals/signals-2018-content-list/articles/water-use-in-europe-2014)  
2767 [europe-2014](https://www.eea.europa.eu/signals/signals-2018-content-list/articles/water-use-in-europe-2014)
- 2768 EEA. (2019). *Floodplains: a natural system to preserve and restore*. European Publications  
2769 Office. Retrieved from <https://data.europa.eu/doi/10.2800/431107>
- 2770 EEA. (2021). *Advancing towards a climate resilience in Europe. Status of reported national*  
2771 *adaptation actions in 2021*. Retrieved January 17, 2023, from  
2772 [https://www.eea.europa.eu/publications/advancing-towards-climate-resilience-in-](https://www.eea.europa.eu/publications/advancing-towards-climate-resilience-in-europe)  
2773 [europe](https://www.eea.europa.eu/publications/advancing-towards-climate-resilience-in-europe)
- 2774 EEA. (2021a). *Nature-based solutions in Europe: policy, knowledge and practice for climate*  
2775 *change adaptation and disaster risk reduction*. Luxembourg: Publications Office of the  
2776 European Union.
- 2777 EEA. (2023b). *Economic losses from weather- and climate-related extremes in Europe*.  
2778 Retrieved from [https://www.eea.europa.eu/en/analysis/indicators/economic-losses-](https://www.eea.europa.eu/en/analysis/indicators/economic-losses-from-climate-related)  
2779 [from-climate-related](https://www.eea.europa.eu/en/analysis/indicators/economic-losses-from-climate-related)
- 2780 EEA. (2024). *European climate risk assessment*. Copenhagen: European Environment Agency.
- 2781 EIOPA. (2019). *EIOPA Staff Discussion Paper. Protection gap for natural catastrophes*.  
2782 Retrieved March 2, 2023, from [https://register.eiopa.europa.eu/Publications/EIOPA-](https://register.eiopa.europa.eu/Publications/EIOPA-19-485_EIOPA%20Staff_Discussion_Paper_Protection_Gap.pdf)  
2783 [19-485\\_EIOPA%20Staff\\_Discussion\\_Paper\\_Protection\\_Gap.pdf](https://register.eiopa.europa.eu/Publications/EIOPA-19-485_EIOPA%20Staff_Discussion_Paper_Protection_Gap.pdf)
- 2784 EU. (2000). *Directive on establishing a framework for Community action in the field of water*  
2785 *policy. Directive 2000/60/EC*. Retrieved from [https://eur-](https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF)  
2786 [lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-](https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF)  
2787 [756d3d694eeb.0004.02/DOC\\_1&format=PDF](https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF)
- 2788 EU. (2007). *Directive on the assessment and management of flood risks. Directive 2007/60/EC*.  
2789 Retrieved from [https://eur-lex.europa.eu/legal-](https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007L0060&from=en)  
2790 [content/EN/TXT/PDF/?uri=CELEX:32007L0060&from=en](https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007L0060&from=en)
- 2791 European Commission. (2010). *Second Follow-up Report to the Communication on water*  
2792 *scarcity and droughts in the European Union COM (2007) 414 fina*. Brussels.

- 2793 European Commission. (2014). *EU Policy Document on Natural Water Retention Measures*.  
2794 Luxembourg: Office for Official Publications of the European Communities.
- 2795 European Commission. (2015). *Directorate-General for Environment, Guidance document on*  
2796 *the application of water balances for supporting the implementation of the WFD – Final*  
2797 *– Version 6.1*. Publications Office. doi:<https://data.europa.eu/doi/10.2779>
- 2798 European Commission. (2019). *5th report on the implementation of the Water Framework*  
2799 *Directive and the Floods Directive*. SWD (2021) 253 final, Brussels. Retrieved  
2800 November 15, 2022, from [https://ec.europa.eu/environment/water/water-](https://ec.europa.eu/environment/water/water-framework/pdf/5th_report/SWD_2021_253.PDF)  
2801 [framework/pdf/5th\\_report/SWD\\_2021\\_253.PDF](https://ec.europa.eu/environment/water/water-framework/pdf/5th_report/SWD_2021_253.PDF)
- 2802 European Commission. (2019a). *Commission Staff Working Document: European Overview -*  
2803 *Flood Risk Management Plans*. Brussels: SWD(2019) 31 final.
- 2804 European Commission. (2020). *Nature-based Solutions: improving water quality & waterbody*  
2805 *conditions: analysis of EU-funded projects*. Luxembourg: Publications Office of the  
2806 European Union.
- 2807 European Commission. (2020a). *Nature-based solutions: state of the art in EU-funded*  
2808 *projects*. Luxembourg: Publications Office of the European Union.
- 2809 European Commission. (2021). *Technical guidance on the climate proofing of infrastructure*  
2810 *in the period 2021-2027*. (2021/C 373/01). Retrieved from [https://eur-](https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021XC0916(03)&from=EN)  
2811 [lex.europa.eu/legal-](https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021XC0916(03)&from=EN)  
2812 [content/EN/TXT/PDF/?uri=CELEX:52021XC0916\(03\)&from=EN](https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021XC0916(03)&from=EN)
- 2813 European Commission. (2021a). *Economic data related to the implementation of the Water*  
2814 *Framework Directive and the Floods Directive and the financing of measures*.  
2815 Directorate-General for Environment Unit ENV.C.1 - Clean Water, Brussels. Retrieved  
2816 from [https://op.europa.eu/en/publication-detail/-/publication/9e25fb48-5969-11ec-](https://op.europa.eu/en/publication-detail/-/publication/9e25fb48-5969-11ec-91ac-01aa75ed71a1/language-en)  
2817 [91ac-01aa75ed71a1/language-en](https://op.europa.eu/en/publication-detail/-/publication/9e25fb48-5969-11ec-91ac-01aa75ed71a1/language-en)
- 2818 European Commission. (2021b). *Impact of climate change on floods : survey findings and*  
2819 *possible next steps to close the knowledge and implementation gap*. DG Environment.  
2820 Publications Office,. Retrieved from <https://data.europa.eu/doi/10.2779/932572>
- 2821 European Commission. (2021c). *Forging a climate-resilient Europe - the new EU Strategy on*  
2822 *Adaptation to Climate*. Brussels. Retrieved from [https://eur-lex.europa.eu/legal-](https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082&from=DE)  
2823 [content/EN/TXT/PDF/?uri=CELEX:52021DC0082&from=DE](https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082&from=DE)
- 2824 Faivre, N. e. (2017). Nature-Based Solutions in the EU: Innovating with nature to address  
2825 social, economic and environmental challenges. *Environmental Research*, 159: 509–  
2826 518.
- 2827 Feyen et al. (2020). *Climate change impacts and adaptation in Europe*. Publications Office of  
2828 the European Union, Luxembourg: JRC PESETA IV final report. doi:0.2760/171121
- 2829 Gómez, Eulalia, Costa, M., M., Egerer, S., & Schneider, U. (2021). *Assessing the long-term*  
2830 *effectiveness of Nature-Based Solutions under different climate change scenarios*.

- 2831 Science of The Total Environment, Volume 794, 2021, 148515.  
2832 doi:<https://doi.org/10.1016/j.scitotenv.2021.148515>.
- 2833 Gómez, M., Máñez, M., & Máñez, K. (2020). *An operationalized classification of Nature*  
2834 *Based Solutions for water-related hazards: From theory to practice*. Ecological  
2835 Economics. Volume 167, 2020, 106460.  
2836 doi:<https://doi.org/10.1016/j.ecolecon.2019.106460>.
- 2837 Haasnoot, M., Kwakkel, J., Walker, W., Maat, & J. (2013). *Dynamic adaptive policy pathways:*  
2838 *a method for crafting robust decisions for a deeply Uncertain world*. Glob. Environ.  
2839 Chang. Part A, 23.
- 2840 Harm, D., Wolters, H., Timboe, I., & Matthews, J. t. (2022). *HELP Guiding Principles for*  
2841 *Drought Risk Management under a Changing Climate. Catalysing actions for*  
2842 *enhancing climate resilience*. Deltares. Retrieved January 26, 2023, from  
2843 [https://www.deltares.nl/app/uploads/2022/03/HELP-Flagship-Report-on-Drought-](https://www.deltares.nl/app/uploads/2022/03/HELP-Flagship-Report-on-Drought-1.pdf)  
2844 [1.pdf](https://www.deltares.nl/app/uploads/2022/03/HELP-Flagship-Report-on-Drought-1.pdf)
- 2845 Hervás-Gámez, C., & Delgado-Ramos, F. (2019). *Drought Management Planning Policy:*  
2846 *From Europe to Spain. Sustainability* . doi: <https://doi.org/10.3390/su11071862>
- 2847 Hofman, E. (2015). *Mainstreaming climate change adaptation in the EU*. Climate Policy Info  
2848 Hub. Retrieved January 17, 2023, from  
2849 <https://climatepolicyinfohub.eu/mainstreaming-climate-change-adaptation-eu.html>
- 2850 Holden et al. (2022). *Nature-based solutions in mountain catchments reduce impact of*  
2851 *anthropogenic climate change on drought streamflow*. Commun Earth Environ 3, 51.  
2852 doi:<https://doi.org/10.1038/s43247-022-00379-9>
- 2853 IPCC. (2014). *Adaptation needs and options*. In: *imate Change 2014: Impacts, Adaptation,*  
2854 *and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working*  
2855 *Group II to the Fifth Assessment Report*. New York, USA.
- 2856 IPCC. (2019). *Special Report on the Ocean and Cryosphere in a Changing Climate*.
- 2857 IPCC. (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of*  
2858 *Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on*  
2859 *Climate Change*. Cambridge University Press. Cambridge University Press,  
2860 Cambridge, UK and New York, NY, USA, 3056 pp., : [H.-O. Pörtner, D.C. Roberts,  
2861 M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S.  
2862 Löschke, V. Möller, A. Okem, B. Rama (eds.)]. doi:10.1017/9781009325844.
- 2863 IPCC. (2022a). *Annex II: Glossary*. In: *Climate Change 2022: Impacts, Adaptation and*  
2864 *Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the*  
2865 *Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, NY,  
2866 USA: Cambridge University Press,. doi:doi:10.1017/9781009325844.029
- 2867 Jeppesen, E., Audet, J., Davidson, T. A., Neif, É. M., Cao, Y., Filiz, N., . . . Søndergaard, M.  
2868 (2021). *Nutrient Loading, Temperature and Heat Wave Effects on Nutrients, Oxygen*

- 2869 and Metabolism in Shallow Lake Mesocosms Pre-Adapted for 11 Years. *Water*, 13,  
2870 127. doi:10.3390/w13020127
- 2871 Kerres M. et al. (2020). *Stop Floatin, Start Swimming. Water and cliate change - interlinkages*  
2872 *and prospects for future action*. Bonn: Deutsche Gesellschaft für Internationale  
2873 Zusammenarbeit (GIZ) GmbH. Retrieved from [https://www.everydrop-](https://www.everydrop-counts.org/imglib/pdf/Water%20Climate%20Report%202020.pdf)  
2874 [counts.org/imglib/pdf/Water%20Climate%20Report%202020.pdf](https://www.everydrop-counts.org/imglib/pdf/Water%20Climate%20Report%202020.pdf)
- 2875 Kind, J., Botzen, W., & Aerts, J. (2020). Social vulnerability in cost-benefit analysis for flood  
2876 risk management. *Environment and Development Economics*, 25(2), 115-134.  
2877 doi:doi:10.1017/S1355770X19000275
- 2878 Marks, M., Liu, J., & Krans, P. (2021). *Ramping-up climate adaptation through a "pathways"*  
2879 *approach*. ICF. Retrieved from [https://www.icf.com/insights/environment/climate-](https://www.icf.com/insights/environment/climate-adaptation-pathways-approach)  
2880 [adaptation-pathways-approach](https://www.icf.com/insights/environment/climate-adaptation-pathways-approach)
- 2881 McAleer, E., Coxon, C., Mellander, P.-E., Grant, J., Richards, & Karl. (2022). Patterns and  
2882 drivers of groundwater and stream nitrate concentrations in intensively managed  
2883 agricultural catchments. *Water*, 14, 1388.
- 2884 Mekong River Commission [MRC]. (2014). *International experiences on the formulation and*  
2885 *implementation of transboundary climate change adaptation strategies*. Vientiane.  
2886 Retrieved from [https://www.mrcmekong.org/assets/Publications/Reports/International-experiences-](https://www.mrcmekong.org/assets/Publications/Reports/International-experiences-on-the-formulation-implt-of-tbr-CCA-strategies.pdf)  
2887 [on-the-formulation-implt-of-tbr-CCA-strategies.pdf](https://www.mrcmekong.org/assets/Publications/Reports/International-experiences-on-the-formulation-implt-of-tbr-CCA-strategies.pdf)
- 2889 Nöges, T. (2009). *Relationships between morphometry, geographic location and water quality*  
2890 *parameters of European lakes*. *Hydrobiologia* 633, 33–43.  
2891 doi:<https://doi.org/10.1007/s10750-009-9874-x>
- 2892 O'Briain, R. (2019). *Climate change and European rivers: An eco-hydromorphological*  
2893 *perspective*. *Ecohydrology*. 12:e2099. doi:<https://doi.org/10.1002/eco.2099>
- 2894 OECD. (2022). *Workshop on Cost Recovery*. Retrieved January 26, 2023, from  
2895 [https://www.oecd.org/water/discussion-highlights-cost-recovery-31-may-1-june-](https://www.oecd.org/water/discussion-highlights-cost-recovery-31-may-1-june-2022.pdf)  
2896 [2022.pdf](https://www.oecd.org/water/discussion-highlights-cost-recovery-31-may-1-june-2022.pdf)
- 2897 OECD. (2022a). *The economics of water scarcity*. Retrieved from  
2898 <https://www.oecd.org/water/background-note-water-scarcity-26-27-april-2022.pdf>
- 2899 OECD. (2022b). *Background note: Water investment planning and financing*. Retrieved from  
2900 [https://www.oecd.org/water/background-note-water-investment-planningand-](https://www.oecd.org/water/background-note-water-investment-planningand-financing-15-16-feb-2022.pdf)  
2901 [financing-15-16-feb-2022.pdf](https://www.oecd.org/water/background-note-water-investment-planningand-financing-15-16-feb-2022.pdf)
- 2902 Pelaez Jara, M. (2020). *The Ascending and Fading of a Progressive Policy Instrument: The*  
2903 *Climate Change Factor in Southern Germany*. *Water*.  
2904 doi:<https://doi.org/10.3390/w12041050>
- 2905 Penning, E. (2022). *Using Nature-Based Solutions to address water security changes*. Madrid:  
2906 Hydrolink 2022/2, International Association for Hydro-Environment Engineering and

- 2907 Research (IAHR). S. 45-47. Retrieved from [https://www.iahr.org/library/download-](https://www.iahr.org/library/download-paperfile?code=CMn85NUgri)  
2908 [paperfile?code=CMn85NUgri](https://www.iahr.org/library/download-paperfile?code=CMn85NUgri)
- 2909 PIANC. (2020). *Climate Change Adaptation Planning for Ports and Inland Waterways*. Report  
2910 of PIANC Technical Working Group No. 178. . Retrieved from  
2911 <https://www.pianc.org/publications/envicom/wg178>
- 2912 Prober, S. M., Colloff, M. J., Abel, N., Crimp, S., Doherty, M. D., Dunlop, M., . . . Williams,  
2913 K. (2017). *Informing climate adaptation pathways in multi-use woodland landscapes*  
2914 *using the values-rules-knowledge framework*. Agriculture, Ecosystem & Environment,  
2915 39-53. doi:<https://doi.org/10.1016/j.agee.2017.02.021>
- 2916 Räike, A., Taskinen, A., & Knuuttila, S. (2020). *Nutrient export from Finnish rivers into the*  
2917 *Baltic Sea has not decreased despite water protection measures*. *Ambio* 49: 460–474.
- 2918 Rieu-Clarke, A., Moynihan, A., Magsig, & B.-O. (2015). *Transboundary water governance*  
2919 *and climate change adaptation: international law, policy guidelines and best practice*  
2920 *application*. UNESCO, Paris. Retrieved from  
2921 <https://unesdoc.unesco.org/ark:/48223/pf0000235678>
- 2922 Rogora, M., Buzzi, F., Dresti, C., Leoni, B., Lepori, F., Mosello, R., . . . Salmaso, N. (2018).  
2923 *Climatic effects on vertical mixing and deep-water oxygen content in the subalpine*  
2924 *lakes in Italy*. *Hydrobiologia*, 824(1), 33–50. .
- 2925 Rossi, L., Wens, M., De Moel, H., Cotti, D., Sabino Siemons, A.-S., Toreti, A., . . . Rudari, R.  
2926 (2023). *European Drought Risk Atlas, Publications Office of the European Union*.  
2927 Luxembourg. doi:10.2760/608737, JRC135215
- 2928 Rouillard & Schmidt. ( 2023). : *Implementation of water allocation in the EU. Developed under*  
2929 *the Framework Contract ‘Water for the Green Deal’ - Implementation and*  
2930 *development of the EU water*. Brussels: European Commission.
- 2931 Sahani et al. (2019). *Hydro-meteorological risk assessment methods and management by*  
2932 *nature-based solutions*. *Science of The Total Environment*, Volume 696, 2019, 133936.  
2933 doi:<https://doi.org/10.1016/j.scitotenv.2019.133936>
- 2934 Schmeier, S. (2018). *What is water diplomacy and why should you care?* Global Water Forum.
- 2935 Schmidt, G., Afonso do, Ó., Agnieszka, M., Benítez-Sanz, C., Tetelea, C., Cinova, D., . . .  
2936 Kampa, E. (2023). *Stock-taking analysis and outlook of drought policies, planning and*  
2937 *management in EU Member States* . European Commission, Directorate-General for  
2938 Environment.
- 2939 Seddon, N., Turner, B., Berry, P., Chausson, A., & Girardin, C. (2019). *Grounding naturebased*  
2940 *climate solutions in sound biodiversity science*. *Nat. Clim. Chang.* 9, 84–87.  
2941 doi:<https://doi.org/10.1038/s41558-019-0405-0>
- 2942 Short, et al. (2016, #nov#). Impacts of climate change on submerged and emergent wetland  
2943 plants. *Aquatic Botany*, 135, 3-17. doi:10.1016/j.aquabot.2016.06.006

- 2944 Siebentritt, M., & Stafford Smith, M. (2016). *A User's Guide to Applied Adaptation Pathways*  
 2945 *Version 1*. Seed Consulting Services and CSIRO. Retrieved from  
 2946 [https://climatelondon.org/wp-content/uploads/2019/10/User-Guide-for-Applied-](https://climatelondon.org/wp-content/uploads/2019/10/User-Guide-for-Applied-Adaptation-Pathways.pdf)  
 2947 [Adaptation-Pathways.pdf](https://climatelondon.org/wp-content/uploads/2019/10/User-Guide-for-Applied-Adaptation-Pathways.pdf)
- 2948 Solheim, L., Globevnik, Austnes, Kristensen, Moe, Persson, . . . Birk. (2019). *A new broad*  
 2949 *typology for rivers and lakes in Europe: Development and application for large-scale*  
 2950 *environmental assessments*. *Science of the Total Environment*, 697.  
 2951 doi:doi.org/10.1016/j.scitotenv.2019.134043
- 2952 Stoffel, M., Tiranti, D., & Huggel, C. (2014). *Climate change impacts on mass movements —*  
 2953 *Case studies from the European Alps*. *Science of The Total Environment*.  
 2954 doi:<https://doi.org/10.1016/j.scitotenv.2014.02.102>.
- 2955 Tascón-González, L., Ferrer-Julà, M., Ruiz, M., García-Meléndez, & E. (2020). *Social*  
 2956 *Vulnerability Assessment for Flood Risk Analysis*. *Water*, 12, 558.  
 2957 doi:<https://doi.org/10.3390/w1202055>
- 2958 Thorslund, J., Bierkens, M., Oude Essink, G., Sutanudjaja, E., Vliet, v., & M. (2021). *Common*  
 2959 *irrigation drivers of freshwater salinisation in river basins worldwide*. *Nat Commun*  
 2960 12, 4232. doi:<https://doi.org/10.1038/s41467-021-24281-8>
- 2961 Trimmel, H., Weihs, P., Leidinger, D., Formayer, H., Kalny, G., & and Melcher, A. (2018).  
 2962 *Can riparian vegetation shade mitigate the expected rise in stream temperatures due*  
 2963 *to climate change during heat waves in a human-impacted pre-alpine river?* *Hydrol.*  
 2964 *Earth Syst. Sci.*, 22, 437–461. doi:<https://doi.org/10.5194/hess-22-437-2018>
- 2965 UNECE & INBO. (2015). *Water and Climate Change Adaptation in Transboundary Basins:*  
 2966 *Lessons Learned and Good Practices*. New York. Retrieved from  
 2967 [https://unece.org/sites/default/files/2021-12/ece.mp\\_.wat\\_.45\\_eng.pdf](https://unece.org/sites/default/files/2021-12/ece.mp_.wat_.45_eng.pdf)
- 2968 UNECE. (2009). *Guidance on water and adaption to climate change*. UNITED NATIONS  
 2969 PUBLICATION. Retrieved from <https://unece.org/info/publications/pub/21691>
- 2970 UNECE. (2020). *Mainstreaming water and transboundary cooperation into climate related*  
 2971 *documents*. Retrieved November 24, 2022, from  
 2972 [https://unece.org/fileadmin/DAM/env/documents/2020/WATER/10Oct02\\_11thTF-](https://unece.org/fileadmin/DAM/env/documents/2020/WATER/10Oct02_11thTF-Wat-Climate/Background_paper_updated_ENGL.pdf)  
 2973 [Wat-Climate/Background\\_paper\\_updated\\_ENGL.pdf](https://unece.org/fileadmin/DAM/env/documents/2020/WATER/10Oct02_11thTF-Wat-Climate/Background_paper_updated_ENGL.pdf)
- 2974 UNEP. (2021). *Guidelines for Integrating Ecosystem-based Adaptation into National*  
 2975 *Adaptation Plans: Supplement to the UNFCCC NAP Technical Guidelines*. Retrieved  
 2976 from <https://wedocs.unep.org/20.500.11822/36703>
- 2977 UNEP. (2022). *Emissions Gap Report 2022*. United Nations Environment Programme.  
 2978 Retrieved from <https://www.unep.org/resources/emissions-gap-report-2022>
- 2979 UNFCCC. (1992). United Nations Framework Convention on Climate Change.
- 2980 van Wesenbeeck et al. (2021). *Economic rationale of NbS in freshwater ecosystems*. Retrieved  
 2981 from [https://www.preventionweb.net/publication/economic-rationale-nbs-freshwater-](https://www.preventionweb.net/publication/economic-rationale-nbs-freshwater-ecosystems)  
 2982 [ecosystems](https://www.preventionweb.net/publication/economic-rationale-nbs-freshwater-ecosystems)

- 2983 WATECO. (2003). *Guidance Document No 1: Common implementation strategy for the WFD*  
 2984 *(2000/60/EC)*. Lu: European Communities.
- 2985 Werners, S., Wise, R. M., Butler, J., Totin, E., & Vincent, K. (2021). *Adaptation pathways: A*  
 2986 *review of approaches and a learning framework*. Environmental Science & Policy.  
 2987 doi:<https://doi.org/10.1016/j.envsci.2020.11.003>
- 2988 Wild, T., Bulkeley, H., Naumann, S., & Vojinovic, Z. (2020). *Nature-Based Solutions State of*  
 2989 *the Art in EU-funded Projects*. Brussels: European Commission.
- 2990 Wise, Fazey, Smith, S., Park, Eakin, Garderen, A. V., & Campbell. (2014). *Reconceptualising*  
 2991 *adaptation to climate change as part of pathways of change and response* . Glob.  
 2992 Environ. Chang., 28.
- 2993 WMO. (2011). *Attribution of Weather and Climate-Related Extreme Events*. World  
 2994 Meteorological Organization.
- 2995 WMO. (2021). *State of the Climate in Europe 2021*. World Meteorological Organisation.  
 2996 Retrieved from  
 2997 [https://library.wmo.int/index.php?lvl=notice\\_display&id=22152#.ZEEExFfbP25d](https://library.wmo.int/index.php?lvl=notice_display&id=22152#.ZEEExFfbP25d)
- 2998 Woolway, R. I., Kraemer, B. M., Lenters, J. D., Merchant, C. J., O'Reilly, C. M., & Sharma,  
 2999 S. (2020, #jul#). Global lake responses to climate change. *Nature Reviews Earth \&*  
 3000 *Environment*, 1-16. doi:10.1038/s43017-020-0067-5
- 3001 World Bank. (2021). *Investment in Disaster Risk Management in Europe Makes Economic*  
 3002 *Sense : Background Report*. Washington DC: World Bank.
- 3003 Zhao, G., Li, Y., Zhou, L., & Gao, H. (2022). Evaporative water loss of 1.42 million global  
 3004 lakes. *Nature Communications*, 13, 3686. doi:10.1038/s41467-022-31125-6
- 3005
- 3006
- 3007

## Getting in touch with the EU

### In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online ([european-union.europa.eu/contact-eu/meet-us\\_en](https://european-union.europa.eu/contact-eu/meet-us_en)).

### On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
- at the following standard number: +32 22999696,
- via the following form: [european-union.europa.eu/contact-eu/write-us\\_en](https://european-union.europa.eu/contact-eu/write-us_en).

## Finding information about the EU

### Online

Information about the European Union in all the official languages of the EU is available on the Europa website ([european-union.europa.eu](https://european-union.europa.eu)).

### EU publications

You can view or order EU publications at [op.europa.eu/en/publications](https://op.europa.eu/en/publications). Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre ([european-union.europa.eu/contact-eu/meet-us\\_en](https://european-union.europa.eu/contact-eu/meet-us_en)).

### EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex ([eur-lex.europa.eu](https://eur-lex.europa.eu)).

### EU open data

The portal [data.europa.eu](https://data.europa.eu) provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

