SEVENTH FRAMEWORK PROGRAMME
THEME 6: Environment (including Climate Change)

Adaptive strategies to Mitigate the Impacts of Climate Change on European Freshwater Ecosystems

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Deliverable 1.4: Integrating strategies at sub-catchment and local scale and strategies at catchment and European scales

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
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Abstract

Practical adaptation, mitigation and restoration strategies are urgently required by river basin managers either to adapt to future climate change or to minimise the effects of future change on current or restored situations.
One of the tasks of REFRESH WP1 is reviewing the effectiveness of adaptation and mitigation measures already being practised in Europe at different scales.

The objective of Task 1 is to collect and review strategies at sub-catchment and local scales for rivers, lakes and wetlands and to combine these with strategies at catchment and European scales.
In this sub-task of task 1 the adaptation strategies and measures already under discussion at sub-catchment and local scales were reviewed and assessed how such strategies are being and can be implemented.

To meet the objective experts from different European climate regions were asked to help to (i) compile a list of local and sub-catchment adaptation measures and (ii) to relate these measures to temperature or precipitation changes (predicted climate change).

For streams and rivers 15 adaptation strategies with a total of 51 adaptation measures were listed. For lakes the experts came up with 11 adaptation strategies with a total of 41 adaptation measures.

Each of the measures was given a score that relates to a specific climate pressure differentiated for the European climate region: Atlantic, boreal, alpine, continental and Mediterranean region. Measures were scored according to one or more climate change effects: no climate change related pressure, temperature rise, increase winter precipitation, summer extremes, water quality and others.

The selected strategies at local and sub-catchment scales were compared with strategies at catchment/basin and European scales. The most important conclusions were:

- habitat restoration measures were far more listed at small scales compared to large ones,
- restoration of the water network occurred at small scale and lacks at large ones,
- water retention storage capacity measures are more often listed at lower scales at large scales more emphasis is on flow restoration, reforestation, floodplain restoration, riparian/buffer zone restoration, improvement of connectivity, and sediment load reduction (especially through run off)

In general, as climate change is still unpredictable the best way to move forward in adaptive management is to strengthen the resistance and resilience of freshwater bodies.

Content

1. Introduction

1.1 Integrating measures at sub-catchment and local scales for rivers, lakes and wetlands and measures at catchment and European scales

Stronger manifestation of climate change impact on global water cycle, water resources, and aquatic ecosystems has given a strong impetus to the development of adaptation and mitigation measures in water management. One of the tasks of WP1 is reviewing the effectiveness of adaptation and mitigation measures already being practised in Europe at different scales. In task 1 the adaptation, mitigation and restoration strategies are reviewed. Practical adaptation, mitigation and restoration strategies are urgently required by river basin managers either to adapt to future climate change or to minimise the effects of future change on current or restored situations. In this sub-task of task 1 the adaptation and mitigation strategies already under discussion at sub-catchment and local scales are reviewed and assessed how such strategies are being and can be implemented. After the review the selected strategies at local and sub-catchment scales are integrated with strategies at catchment/basin and European scales. This Deliverable will be the basis for a practical guide that lists the most effective management strategies for use throughout Europe.

1.2 Objective

To collect and review strategies at sub-catchment and local scales for rivers, lakes and wetlands and to combine these with strategies at catchment and European scales.

1.3 Measures in the 1st River Basin Management Plans

In the 1st River Basin Management Plans (RBMPs) most European countries included a chapter that described the observed climate change and its impacts to water resources management. The climate change paragraph(s) aimed to ensure that the Programmes of Measures (PoMs) were sufficiently adaptive to future climate conditions, based on available knowledge, data and common sense. For this climate change proof checking the European countries had to assess whether the planned measures, especially when these measures that have a long lifetime, remain effective under the likely or possible future climate conditions and favour measures that are robust and flexible to the uncertainty and cater for the range of potential variation related to future climate conditions. Favoured should be sustainable adaptation and mitigation measures, especially those with cross-sectoral benefits, and which have the least environmental impact, including greenhouse gas emissions. Most countries had carried out the 'climate checking' of their measures but the results were reported with a very different level of detail. The distinction of specific climate change measures from the complex of measures dealing with floods, droughts and water quality protection, was rather arbitrary. In some countries, for instance, when a link between climate change and flood frequency was proven, there was a tendency to qualify all flood protection measures as climate change adaptation measures and the same is valid for drought prevention and water quality protection measures (Noges et al. 2010a, REFRESH D1.1). In the REFRESH Deliverable 1.1 231 climate change adaptation measures were listed based on all European RBMPs, thus the national and European level.

1.4 Measures at catchment and European scales

In the REFRESH Deliverable 1.2 Noges et al. (2010) extended the list of potential and planned water related measures tackling climate change causes and consequences, which have been included in the Member States River Basin Management Plans, published in various reports and scientific literature mostly within the last decade. The database of about 450 measures are defined as practical steps or actions taken to

a. reduce the sources or enhance the sinks of greenhouse gases,
b. to decrease the vulnerability of water resources and aquatic ecosystems to climate change,
c. enhance the knowledge base on climate-water relationships and increase the societal capacity to take right decisions on this matter.

By strategic approach, the measures belong either to planned adaptation, which specifically focuses on climate change and variability, and autonomous adaptation, which goals are not specifically climate related, but have an added value in improving resilience to climate change.

2. Methods

As it was impossible to approach all water managers in Europe to learn about local adaptation measures we alternatively approached experts from different European climate regions to help to (i) compile a list of local and sub-catchment adaptation measures and (ii) to relate these measures to temperature or precipitation changes.

First, based on the Dutch water managers experiences, a list of measure for streams and rivers and for small and large-deep lakes in the Atlantic region was compiled. Therefore, a selection of WFD measures was made that help to mitigate or adapt to climate change at a sub-catchment and local scales. This list with local, sub-catchment and regional adaptation measures was send to a number of experts in other climate regions as well as to other experts in the Atlantic region as there are possibly more measures applied. A resulting Excel file includes a list of all local and regional measures for (i) streams and lakes (including riparian zone), and (ii) for small and large lakes.

Next, these measures were given a score that relates each measure to a specific climate pressure differentiated for the European climate region: Atlantic, boreal, alpine, continental and Mediterranean region (Table 1). Measures were scored with the number(s) that corresponds to the one or more climate change effects. For example, the measure 'forestation' can be taken in Atlantic streams and is a adaptation measure against temperature rise, increase in winter precipitation and summer extremes.

Table 1. Score that relates each measure to a specific climate pressure.

score	climate change induced pressure	example
0	no climate change related pressure	
1	temperature rise	direct, like warming, stratification
2	increase winter precipitation	direct effects, like run off, water level fluctuation, spates, inundation
3	summer extremes	direct effects, like droughts, spates
4	water quality	indirect effects, like nutrient cycling, eutrophication, oxygen regime changes, salt seepage
5	others	indirect effects, like exotic species, terrestrialisation

This overview can be used by local authorities to select those local measures that also serve as adaptation measures (these measures have thus an added value). The resulting list will become part of the practical guide of integrated adaptation strategies for water managers.

3. Results

3.1 Resistance and resilience

A holistic understanding of the pathways of climate change influence on surface waters underscores the need for an integrated approach to adapting, mitigating or restoring aquatic ecosystems. To be effective, management programs designed to prevent degradation of surface waters or restore previously degraded systems should consider the breadth of pressures occurring in a basin to determine which are the most influential on water ecosystems. Restoration of historic surface water structures and processes may be critical to the re-establishment of historic conditions. But not all situations are reversible and one has to take also future conditions into account when designing adaptation strategies for climate change.

Adaptation strategies for water management include those responses or actions undertaken to enhance (i) resistance, (ii) resilience, and (iii) change of vulnerable aquatic systems (Millar et al. 2007), thereby reducing damages these systems from climate change and variability (Lawler 2009).

- Resistance is the ability of a system to remain unchanged in the face of external forces. Resilience can be defined as the ability of a system to recover from perturbations (Holling 1973).
- A resilient system will change in response to external forces, like climate change, but will return to its original state. With respect to climate change, systems that are more resilient are those that are better able to adapt to changes in climate. Resilient systems will continue to function, albeit potentially differently, in an altered climate. Less resilient systems will likely undergo messy transitions to new states, resulting in the loss of ecosystem functioning, populations, or even species. Resilience and resistance enable persistence.
- Strategies that promote change are those designed to accept change and to help move a system from one state to another (accommodation).

The extent to which climate change may alter an aquatic ecosystem is called its vulnerability. It depends not only on the ecosystem's sensitivity but also on its ability to adapt to new climatic conditions (Figure 1).
Adaptation strategies in practices, processes, or structures of aquatic ecosystems will be needed either to reduce the sensitivity of systems to changes in climatic conditions or to exploit new opportunities. The actions may be taken in reaction to climate change as it occurs (i.e. reactive or passive adaptation) or in anticipation of future climate change (i.e. anticipatory or active adaptation).

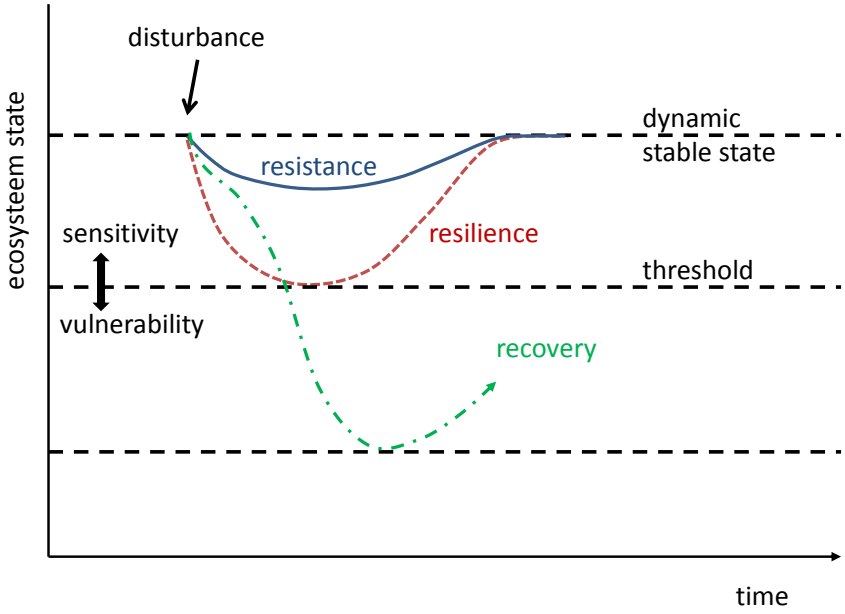

Figure 1. Illustrations of the different terms related to the behaviour of ecosystems after disturbance (van Andel et al. 2012).

The most commonly recommended adaptation strategies for promoting resistance, resilience, and change are (Lawler 2009):

1. Removing and reducing additional stressors

Perhaps the most obvious approaches to increasing resilience are the removal or reduction of other, non-climate-related stressors to an aquatic ecosystem. Decreasing eutrophication, acidification, habitat loss and fragmentation, hydromorphological change, the impact of exotic species, and other stressors generally results in more robust functioning ecosystems that comprise higher biodiversity and that will likely be better able to absorb perturbations. Not only do other stressors reduce the ability of an ecosystem to respond to or to absorb new impacts, but in many cases, climate change may exacerbate the effects of other stressors. For example, increases in temperature may increase nutrient loads in lakes, the toxicity of pesticides or the infection rates and severity of diseases (Kumaraguru & Beamish 1981). Likewise climate change may increase competitive pressure from invasive species, as some invasive species may benefit from rising temperature or changing precipitation, allowing them to spread and/or outcompete native species (e.g. Rahel & Olden 2008).

2. Expanding the area of aquatic habitats

Climate change will challenge the ability of the current surface waters to provide habitat for species and ecosystems when the climate shifts so much that plants and animals no longer thrive where their current habitats are located. Many studies suggested to improve the quality (see point 1) and to increase the area of the 'more natural' aquatic habitats to give ecosystems and species room to move and place to go. Increasing redundancy in aquatic habitats, thus increasing their total area, can also increase resilience by providing more opportunities in different places or chances in which species or communities might persist.

3. Increasing the connectivity between habitats

In the past, species have moved across continents as climates changed and glaciers advanced and retreated (Davis & Shaw 2001). One of the biggest differences between those historic periods and today is that humans have dramatically altered the stream and river networks and their floodplains as well as lakes and their basins. Agricultural land uses, dams, channelized sections and

water diversions, urban areas, and other interferences act as barriers to movement for species. These barriers will make it difficult for many species to move from water bodies that have become unsuitable to suitable ones or to occupy new climatic zones or habitats that emerge in the future in other regions. The highly fragmented nature of today's waterscapes has led many ecologists to promote increasing connectivity among high quality water bodies to enhance movement in a changing climate (Hulme 2005). Given that many species, with diverse habitat requirements and dispersal abilities, will need to move in response to climate change, species based corridor approaches may not be adequate or feasible (Hulme 2005). Two additional approaches to increasing connectivity have been proposed: (i) small steppingstones like high quality ponds or restored stream sections, to facilitate movement, and (ii) to manage the waters between high quality waters in ways that allow the most species to move through these bodies.

4. Restoring habitat and ecosystem processes

Clearly, the restoration of habitat and ecosystem functioning in degraded water bodies plays a key role in increasing resilience. Many have highlighted the need to restore functioning ecosystems to address climate change (e.g. Mulholland et al. 1997). However, climate-induced changes in hydrology, disturbance regimes, and species distributions will make restoration goals moving targets (Harris et al. 2006). Up to now, most current restoration aims to return a system to historic or predisturbance conditions (Swetnam et al. 1999). In some cases, this may still be a viable option but for many aquatic ecosystems, climate change will make it costly if not impossible to recreate past ecological states. Furthermore, often current restoration focuses on restoring species or community composition. Successfully restoring specific species assemblages will require relatively accurate predictions of which sites will be suitable for which species in the future and how those species will interact under projected climatic conditions (Lawler 2009). Given the uncertainty inherent in future climate projections, our limited knowledge of species-specific responses to climate change, and the inherent uncertainties in most ecological forecasting tools, it is unlikely that we will soon have future predictions that are accurate enough to successfully describe specific species assemblages at a given site in the distant future (Harris et al. 2006, Lawler 2009). An alternative would be restoring processes and functioning in which species assemblages change with changing climates, but ecosystem functioning is secured. Several suggestions have been made for restoring disturbance regimes, river and streamflow regimes, and wetland hydrology (Hartig et al. 1997, Harris et al. 2006).

3.2 Adaptive management

In theory, adaptive management allows for the management of highly uncertain systems as it involves an iterative process in which managers learn from experimental management actions and adapt management actions to it (Holling 1978, Walters & Hilborn 1978). Therefore, adaptive management is well suited for dealing with the uncertainties surrounding future climatic changes (Arvai et al. 2006). Passive adaptive management generally involves building a management strategy based on historic data and then altering that strategy with new data as the system is monitored over time. Active adaptive management involves conscious experimentation, generally exploring the outcomes of multiple management strategies. Both types of adaptive management will likely be needed to address climate change (Lawler 2009).

Applying adaptive management to address climate change will be an iterative multistep process (Kareiva et al. 2008):

1. Assessing the potential impacts of climate change on a system.
2. Designing management to address these impacts.

3. Monitoring for both climatic changes and potential system responses.
4. Re-evaluating and potentially redesigning of chosen strategies (cycle).

Whereas a more traditional approach to active adaptive management might involve simultaneously testing several alternative management strategies to attain a set goal, active adaptive management for climate change will require testing several different management strategies designed to attain different goals under different climate change scenarios. Developing the different scenarios and goals will require knowledge of the range of plausible future climate-change projections and some estimate of how those different climatic changes will affect the system or species in question. This type of scenario based approach will require managers to think in parallel, in essence, planning for a system with several potential future states.
Effectively managing aquatic systems in a changing climate will require taking a broader spatial and temporal perspective (Scott et al. 2002). Instead of considering a community or ecosystem in isolation, it will be essential to manage these within a catchment, supra-catchment or regional context.

To accomplish an effective adaptation management strategy, basin, watershed or catchment system analysis is a powerful assessment tool (e.g. Montgomery et al. 1995). The analysis should include an assessment of historic, current and future ecosystem structures and processes, thereby providing a referent for assessing the potentials for future conditions. It should also attempt to document, in a spatially explicit manner, the hydrological, morphological and physic-chemical structures, processes and pathways in the whole basin or catchment. This is the basis for making strong inferences regarding causal linkages between management activities and current and future degradation by climate change. An exemple for the improvement of cooling is given in Figure 2.

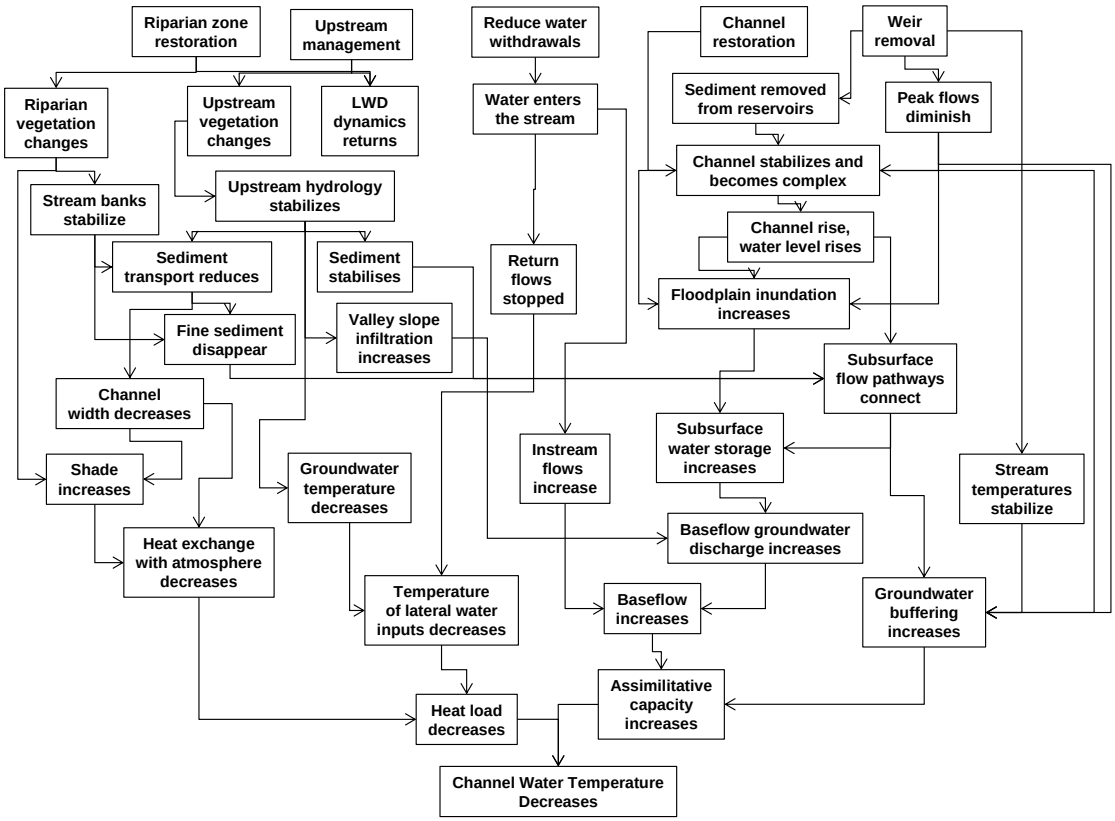

Figure 2. Example of applying the adaptation measure cooling (restoring the riparian zone) in streams (altered after Poole & Berman 2000).

3.3 Adaptation strategies in streams and rivers

Riparian restoration has been proposed as one of the most important methods to reduce stream temperatures and create cool water refugia (Palmer et al. 2008, Scott et al. 2008). Furthermore, riparian zones or wetlands provide connectivity among some terrestrial systems, filter run off of soluble substances, like nutrients and toxic components, as well as organic material and sediments, offer habitat and supply the stream with coarse and fine organic material.
Springs and upper courses can be important thermal refugia that enhance the ability of cold-water macroinvertebrates and fish to persist as temperatures rises (Hansen et al. 2003).
A number of management actions have been suggested for dealing with increases and decreases in flows (Palmer 2008), like:

- channel reconfiguration,
- dam removal or retrofit,
- floodplain restoration,
- dam-based flow management,
- bank stabilization,
- creating wetlands and off-channel basins for water storage during times of extreme flows,
- removal of sediment from reservoirs to increase water storage capacity,
- reducing water extraction to maintaining flows.

For streams and rivers 15 adaptation strategies were distinguished:

1. riparian/buffer zone restoration
2. increase water retention capacity
3. increase water storage capacity
4. floodplain restoration
5. restoration of the water network
6. flow restoration
7. flow restoration, improve connectivity
8. channel shape restoration
9. habitat restoration
10. sediment load reduction
11. improve connectivity
12. nutrient load reduction
13. organic load reduction
14. toxic load reduction
15. reduce direct human interference

3.4 Adaptation strategies in lakes

For both streams and rivers and lakes 11 adaptation strategies were distinguished:

1. increase water storage capacity
2. increase water retention capacity
3. reduce direct human interference
4. habitat restoration
5. improve connectivity
6. nutrient load reduction
7. organic load reduction
8. re-oxygenation
9. toxic load reduction
10. de-salinisation
11. reduce direct human interference

3.5 Adaptation measures in streams and rivers

For streams and rivers 51 adaptation measures were listed on local and sub-catchment scale (Table 2). Not all measures are likely to be useful in any one catchment. Determining which human activities have been or may be most influential on the running water ecosystem is important for designing an effective adaptation management strategy.

3.6 Adaptation measures in lakes

For lakes 40 adaptation measures were listed on local and sub-catchment scale (Table 3). Not all measures are likely to be useful in any one catchment or basin. Determining which human activities have been or may be most influential on the surface water ecosystem is important for designing an effective adaptation or mitigation management strategy.

3.7 Adaptation strategies at catchment and European scales

Noges et al. (2010b) elaborated the five specific adaptation strategies at catchment and European scale addressed in the REFRESH Project. They build a database with 451 adaptation measures and analysed their specific features (Appendix 1). These measures were defined as practical steps or actions taken to (i) reduce the sources or enhance the sinks of greenhouse gases, (ii) to decrease the vulnerability of water resources and aquatic ecosystems to climate change, or (iii) enhance the knowledge base on climate-water relationships and increase the societal capacity to take right decisions on this matter. In their approach they differentiated between measures belonging either to planned adaptation, which specifically focuses on climate change and variability, and autonomous adaptation, which goals are not specifically climate related, but have an added value in improving resilience to climate change.
What becomes very clear is that almost 50% of all adaptation strategies relate to activities that not directly relate to strategies or measures, like, scenario calculations, monitoring, stakeholder participation, communication or planning (Appendix 1). Also about one quarter to one third of the measures are related to the sub-catchment or local scales (Table 4). Most measures are external thus tackle problems outside water bodies. Also one third relates to measures that tackle sources of problems instead of effects.

Table 4. Classification of catchment and European scales strategies according to scale, type and source or effect orientation.

		number	%
Scale	European/national	47	10
	Catchment	116	26
	Sub-catchment	155	34
	Local	117	26
Type	Legislation/Communication/Planning	49	11
	External measure	160	35
	Internal measure	37	8.2
Source or effect	Source or effect	139	31
	Effect	68	15

Table 2. Adaptation measures in streams and rivers.

				water type						
ecosystem component/scale	**climate change effect**	**adaptation strategy**	**adaptation measure**	**stream**	**river**	**atlantic**	**boreal**	**alpine**	**conti-nental**	**mediter-ranean**
temperature	warming of surface water	cooling	(re)forestation	1		1,2,3	1,2,3	1,3,4	1,2,3,4	1,2,3
		cooling	development of a wooded bank	1		1	1	1,4	1,4	1,4
hydrology	change in flow regime	increase water storage capacity	drainage removal	1		2,3,4	2,3,4	2,3,4		1,3,4
		increase water storage capacity	groundwater storage	1	1	3	3	2,3	3	1,3,4
		increase water storage capacity	improvement of infiltration in the soil, like wadi's	1	1	2,3,4	2,3,4	2,3,4	2,3,4	1,3,4
		increase water retention capacity	creation of inundation zones	1	1	2,3	2,3,4	2,3,4	2,3	2,4
		increase water retention capacity	excavation of the uper layer of the riparian zones/floodplain	1	1	2,3,4	2,3,4	2,3,4	2,3,4	1,3,4
		increase water retention capacity	construction of waterretention/retention reservoirs/ponds	1	1	2,3	2,3,4	1,2,3	2,3	1,2,3,4
		increase water retention capacity	digging of high-water channels	1	1	2,3	2,3	2,3	2,3	2
		increase water retention capacity	construction of a two-stage channel	1		2,3	2,3	0	2,3	
		increase water retention capacity	enlargement of the riverbed		1	2,3	2,3,4	2,3,4	2,3,4	2
		increase water retention capacity	reconnection of old meanderbeds	1	1	2,3	2,3,4	0	2,3	2,4
		increase water retention capacity	relocation of dikes to enlarge the riverbed		1	2,3	2,3,4	3,4	2,3	2,4
		restoration of the water network	restoration of natural river network	1		0	0	1,2,5		1,2,3,4
		flow restoration, improve connectivity	removal of weirs	1		1	1	1.2	1,4	1,2,3,4
		flow restoration	introduction of weirs		1	2,3	2,3,4	0	2,3	3

				water type						
ecosystem component/scale	**climate change effect**	**adaptation strategy**	**adaptation measure**	**stream**	**river**	**atlantic**	**boreal**	**alpine**	**conti-nental**	**mediter-ranean**
		flow restoration	removal of obstacles from the floodplain		1	2,3	2,3	3,4	2,3	1,2,3,4
		increase water storage capacity	construction of hydrological buffers	1		2,3,4	2,3,4	2,3,4	2,3,4	2
	change in effective moisture	flow restoration	reduction of water extractions	1		2,3	2,3	1,2,3,4	3	3,4
		increase water retention capacity	reuse of treated wastewater	1		3	3	3	3	4
morphology	erosion	channel shape restoration	passive remeandering	1		2,3	2,3,4	2,3	3	2,4
		channel shape restoration	passive rebraiding	1	1	2,3	2,3,4	2,3	3	2,4
		channel shape restoration	removal of bed fixation	1		0	0	0	3	2,3,4
	change in flow regime	channel shape restoration	digging of new meanders	1	1	2,3	2,3,4	0	3	3,4
		flow restoration	reduction of the wet profile	1	1	0	0	3		3,4
	sedimentation	sediment load reduction	construction of sediment buffers	1		2,3,4	2,3,4	4	2,3,4	4
	loss of biodiversity	habitat restoration	construction of asymmetric/natural bank profiles	1	1	0	0	0	0	0
		habitat restoration	improvement of habitat heterogeneity (micromeandering)	1		0	0		3,4	0
		habitat restoration	improvement of habitat heterogeneity (pools and runs)	1		0	0	1,3,5	4	0
		habitat restoration	improvement of habitat heterogeneity (obstacles)	1	1	0	0	3,5	3,4	3
		habitat restoration	addition of species-specific structures, like fish habitats	1		0	0	1,3,5	0	0
		habitat restoration	reprofiling of banks (steep and overhanging)	1		0	0	0	0	0

				water type						
ecosystem component/scale	**climate change effect**	**adaptation strategy**	**adaptation measure**	**stream**	**river**	**atlantic**	**boreal**	**alpine**	**conti-nental**	**mediter-ranean**
	spread of alien species	habitat restoration	improvement of habitat heterogeneity			0	0	1,3,4,5	4	0
water quality		nutrient load reduction	reduction of the use of fertilizers	1		4	4	4	3,4	4
		nutrient/organic/toxic load reduction	removal of point sources of pollution	1	1	4	4	4	3,4	4
		nutrient/organic/toxic load reduction	removal of sewage discharges (houses)	1		4	4	4	4	4
		nutrient/organic/toxic load reduction	reduction in sewage overflows/load	1	1	4	4	4	4	4
		nutrient/organic/toxic load reduction	improvement of sewage treatment	1		4	4	4	3,4	4
		nutrient/organic/toxic load reduction	separation of sewage and rain water overflow	1	1	4	4	4	3,4	4
		nutrient/organic/toxic load reduction	disconnection of polluted tributaries	1		4	4	4	4	3,4
		nutrient/organic load reduction	creation of helophyte filters/wetland	1		4	4	0	4	3,4
		nutrient/organic load reduction	construction of horse-shoe wetlands	1		4	4	0	4	3,4
		nutrient/organic load reduction	construction of buffer zones between floodplain and agricultural land	1		4	4	4	4	3,4
		nutrient/organic/toxic load reduction	dredging		1	4	4	4	4	4
biology	loss of biodiversity	reduce direct human interference	reintroduction of species, like fish stocking	1	1	0	0	5	0	0
floodplain	loss of biodiversity	habitat restoration	digging of off-channel ponds	1		0	0	0	0	0
	change in flow regime	reduce direct human interference	reduction of maintenance	1	1	1,2,3,4,5	1,2,3,4,5	1,3	1,2,3,4	
	change in flow regime	floodplain restoration	development of a natural floodplain		1	1,2,3,4,5	1,2,3,4,5	3,4	1,2,3,4	2,3,4
connectivity	loss of biodiversity	improve connectivity	construction of fish passages	1		0	0	5	0	0

				water type						
ecosystem component/scale	**climate change effect**	**adaptation strategy**	**adaptation measure**	**stream**	**river**	**atlantic**	**boreal**	**alpine**	**conti-nental**	**mediter-ranean**
societal		outside scope	regulation of recreation pressures	1		0	0	0	0	0
		outside scope	assignment of protected areas	1	1	0	0	5	0	0

Table 3. Adaptation measures in lakes.

				water type							
ecosystem component/ scale	**climate change effect**	**adaptation strategy**	**adaptation measure**	**small lake**	**large/ shallow lake**	**large/ deep lake**	**atlantic**	**boreal**	**alpine**	**conti-nental**	**mediter-ranean**
temperature	warming of surface water	none		1	1	1	0	0	0		1
hydrology	change in water level regime	increase water storage capacity	drainage removal	1	1	1	2,3	2,3,4	2,3,4	2,3,4	
		increase water storage capacity	groundwater storage	1	1	1		2,3	2,3	2,3	
		increase water storage capacity	improvement of infiltration in the soil, like wadi's	1		1	2,3,4	2,3,4	2,3,4	2,3,4	
		increase water retention capacity	construction of waterretention/retention reservoirs/ponds	1	1		2,3	2,3,4	2,3,4	2,3,4	2
		increase water retention capacity	improvement of hydrological isolation			1	2,3,4	2,3,4	2,3,4	2,3,4	
		increase water retention capacity	water level management	1	1	1	2,3	3,4	3,4		3,4
		increase water retention capacity	reduction of water level extractions			1	2,3	2,3,4	2,3,4	2,3,4	3,4
		reduce direct human interference	reduction of maintenance	1			2,3	2,3,4	2,3,4	2,3,4	
		increase water storage capacity	construction of hydrological buffers	1			2,3,4	2,3,4	2,3,4	2,3,4	
	change in effective moisture	increase water retention capacity	reduction of extractions	1			2,3	2,3	2,3,4	2,3	
morphology	erosion	habitat restoration	protection/reconstruction of the banks (stabilisation by vegetation)	1		1	2,3	2,3,4	2,3	2,3	2,4
	siltation / low water level (due to low precipitation & high evaporation) / low freshwater inlet/ loss of connectivity	nutrient/organic/toxic load reduction	dredging	1	1	1	4	2,3,4	2,3,4	4	3,4

				water type							
ecosystem component/ scale	**climate change effect**	**adaptation strategy**	**adaptation measure**	**small lake**	**large/ shallow lake**	**large/ deep lake**	**atlantic**	**boreal**	**alpine**	**conti-nental**	**mediter-ranean**
	loss of biodiversity	habitat restoration	improvement of bank heterogeneity/vegetation				0	2,4	2,3,4	4	
	loss of biodiversity	habitat restoration	construction of natural bank profiles	1		1	0	4	2,4	0	
water quality	eutrophication	nutrient/organic load reduction	creation of helophyte filters/wetland	1	1		4	4	4	4	4
		nutrient/organic load reduction	construction of horse-shoe wetlands	1	1		4	4	4	4	4
		nutrient load reduction	freshwater inlet en flushing	1	1	1	4	4	4		4
		nutrient load reduction	reduction of the use of fertilizers	1	1		4	4	4	4	4
		nutrient/organic load reduction	construction of buffer zones with agricultural land	1	1		4	4	4	4	4
		nutrient load reduction	chemical phosphate removal			1	4	4	4	4	4
		nutrient load reduction	fixation of phosphate in the sediment (addition binding substances)			1	4	4	4	4	
		nutrient load reduction	introduction of zebra mussels			1	4	4	4	4	
		nutrient load reduction	P-fixation	1		1	4	4	4	4	
		nutrient load reduction	introducing rotting strow	1		1	4	4	4	4	
	oxygen depletion	nutrient load reduction, re-oxygenation	flushing		1	1	4	4	4	4	4
	oxygen depletion by stratification	re-oxygenation	mixing		1	1	4	4	4	4	4
	eutrophication/increase toxicity	nutrient/organic/toxic load reduction	reduction in sewage overflows/load / stringent waste water treatment & control system in	1	1	1	4	4	4	4	4

				water type							
ecosystem component/ scale	**climate change effect**	**adaptation strategy**	**adaptation measure**	**small lake**	**large/ shallow lake**	**large/ deep lake**	**atlantic**	**boreal**	**alpine**	**conti-nental**	**mediter-ranean**
			catchment								
	eutrophication/increase toxicity	nutrient/organic/toxic load reduction	removal of point sources of pollution	1	1	1	4	4	4	4	4
	eutrophication/increase toxicity	nutrient/organic/toxic load reduction	removal of sewage discharges (houses)	1	1	1	4	4	4	4	4
	eutrophication/increase toxicity	nutrient/organic/toxic load reduction	dredging	1		1	2,3,4	2,3,4	2,3,4	4	4
	salinisation	de-salinisation	freshwater inlet/flushing	fresh water inlet/flushing	1		4	4	4	0	4
biology	loss of biodiversity	reduce direct human interference	reduction of fish biomass		1	1	4	4	4	4	4
		reduce direct human interference	fish (predatory) stocking		1	1	4	4	4	4	4
		reduce direct human interference	shellfish stocking			1	4	4		0	
		reduce direct human interference	removal of exotics		1	1	0	0	0	0	
	spread of alien species	habitat restoration	improvement of habitat heterogeneity/managing alien species	1	1	1	0	0	0	0	
floodplain	loss of biodiversity	habitat restoration	development of natural bank vegetation		1	1	0	2,4	2,4	0	
connectivity	loss of biodiversity	improve connectivity	construction of fish passages/reduction of fish migration barrieres		1	1	0	0	0	0	
		increase water retention capacity	connection of waterbody and floodplain/adjacent wetland		1	1	0	2,4	2,4	4	
societal		outside scope	regulation of recreation pressures incl. fishing		1	1	4	4	4	4	

4. Integrating large and small scales

4.1 Comparing catchment and European scales with sub-catchment and local ones

Analysis of all 451 adaptation strategies at catchment and European scale showed that almost half of the strategies/measures listed were not applicable to the practical level of sub-catchment or local scales as approached by water managers (Table 5).

Table 5. Summary overview of adaptation strategies at catchment and European scale (n=451).

adaptation strategy	number	%
increase water storage capacity	18	4.0
increase water storage capacity, improve connectivity, stream restoration	1	0.2
increase water storage capacity, nutrient/organic/toxic load reduction	1	0.2
increase water retention capacity	20	4.4
flow restoration	20	4.4
reforestation	6	1.3
floodplain restoration	11	2.4
riparian/buffer zone restoration	17	3.7
channel shape restoration	12	2.6
channel shape restoration, habitat restoration	1	0.2
habitat restoration	2	0.4
improve connectivity	12	2.6
sediment load reduction	12	2.6
nutrient load reduction	28	6.2
nutrient/organic load reduction	7	1.5
nutrient/organic/toxic load reduction	4	0.9
toxic load reduction	4	0.9
toxic/nutrient load reduction	1	0.2
reduce direct human interference	1	0.2
invasives	1	0.2
coast	14	3.1
outside scope	216	47.6
negative	13	2.9

The more often listed strategies relate to nutrient load reduction, increase of water storage or retention capacity, flow restoration and riparian/buffer zone restoration. Most others were listed less in than 3% of all cases.

For streams and rivers increase of water retention capacity, habitat restoration and nutrient, organic and toxic load reduction were mostly listed (Table 6).

Table 6. Summary overview of adaptation strategies at sub-catchment and local scale (n=51) for streams and rivers.

adaptation strategy	number	%
riparian/buffer zone restoration	2	3.9
increase water retention capacity	9	17.6
increase water storage capacity	4	7.8
floodplain restoration	1	2.0
restoration of the water network	1	2.0
flow restoration	4	7.8
flow restoration, improve connectivity	1	2.0
channel shape restoration	4	7.8
habitat restoration	8	15.7
sediment load reduction	1	2.0
improve connectivity	1	2.0

nutrient load reduction	1	2.0
nutrient/organic load reduction	3	5.9
nutrient/organic/toxic load reduction	7	13.7
reduce direct human interference	2	3.9
outside scope	2	3.9

Also for lakes increase of water retention capacity, habitat restoration and nutrient, organic and toxic load reduction, and reduce direct human interference were mostly listed (Table 7).

Table 7. Summary overview of adaptation strategies at sub-catchment and local scale (n=41) for lakes.

adaptation strategy	**number**	**%**
none	1	2.4
increase water storage capacity	4	9.8
increase water retention capacity	6	14.6
habitat restoration	5	12.2
improve connectivity	1	2.4
nutrient load reduction	7	17.1
nutrient/organic load reduction	3	7.3
nutrient load reduction, re-oxygenation	1	2.4
re-oxygenation	1	2.4
nutrient/organic/toxic load reduction	5	12.2
de-salinisation	1	2.4
reduce direct human interference	5	12.2
outside scope	1	2.4

4.2 Conclusions

Comparing the adaptation strategies at different scales most obvious and least surprising is the 12 to 15 time's higher number of habitat restoration measures at small scales versus large ones (Table 8). Also surprising is the restoration of the water network that occurs for streams and rivers at small scale but lacks at large scales. Also water retention storage capacity measures are higher at lower scales which does not account for water storage capacity measures that are comparable at both scales. At large scales more emphasis is on flow restoration, reforestation, floodplain restoration, riparian/buffer zone restoration, improvement of connectivity, and sediment load reduction (especially through run off). The latter group of adaptation strategies all act at larger scales or can better/only be taken at larger scales.
Of course when comparing streams and rivers with lakes a number of adaptation strategies is more or only related to water type, like flow restoration, floodplain restoration, channel shape restoration in streams and rivers versus nutrient load reduction, reduction of direct human interference or re-oxygenation in lakes.

Table 8. Comparison of adaptation strategies on catchment and European or large scale (scaled to 100%) versus sub-catchment and local or small scale.

Scale	**large**	**small**	
Water type		**streams and rivers**	**lakes**
Adaptation strategy	**%**	**%**	**%**
increase water storage capacity	10.1	7.8	9.8
increase water storage capacity, improve connectivity, stream restoration	0.6		
increase water storage capacity, nutrient/organic/toxic load reduction	0.6		
increase water retention capacity	11.2	17.6	14.6
flow restoration	11.2	7.8	
reforestation	3.4		

floodplain restoration	6.1	2.0	
riparian/buffer zone restoration	9.5	3.9	
channel shape restoration	6.7	7.8	
channel shape restoration, habitat restoration	0.6		
habitat restoration	1.1	15.7	12.2
improve connectivity	6.7	2.0	2.4
sediment load reduction	6.7	2.0	
nutrient load reduction	15.7	2.0	17.1
nutrient/organic load reduction	3.9	5.9	7.3
nutrient/organic/toxic load reduction	2.2	13.7	12.2
toxic load reduction	2.2		
toxic/nutrient load reduction	0.6		
reduce direct human interference	0.6	3.9	12.2
invasives	0.6		
restoration of the water network		2.0	
flow restoration, improve connectivity		2.0	
nutrient load reduction, re-oxygenation			2.4
re-oxygenation			2.4
de-salinisation			2.4

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Appendix 1. Adaptation strategies and measures at catchment and European scale (Noges et al. 2010).

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M001	Managing industrial accident risk		1				1			1	
M002	Bypasses and culverts (roads, railway).	improve connectivity				1			1		1
M003	Development of large and micro-scale hydropower capacities.	outside scope									
M004	Removal of hydropower plant (storage)	flow restoration		1	1			1		1	
M005	Sustainable Urban Drainage Systems (SUDS)	increase water storage capacity			1	1		1		1	
M006	New water treatment infrastructure or other measures within floodplains.	flow restoration		1	1			1		1	
M007	Registration of abstraction structures		1				1			1	
M008	Solve quantitative unbalance		1				1			1	
M009	Decrease drainage of groundwater by canals	increase water storage capacity			1	1		1		1	
M010	Measures to improve supply that are not supported by demand management measures, e.g. building reservoirs in order to safeguard irrigation in areas with limited resources.	negative		1	1			1		1	
M011	Implementation of collective organisation of irrigation		1				1			1	
M012	Classification of river basins in deficit		1	1			1			1	
M013	Implementation of river basin plans		1	1			1			1	

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M014	Measures to deal with abstraction pressures e.g. abstraction licensing.		1				1			1	
M015	Education and advice is needed to ensure efficient adaptation at farm and regional scales		1				1			1	
M016	Education, information, consulting for farmers		1				1			1	
M017	Storm water detention basins	increase water retention capacity		1	1			1			1
M018	Integrated projects that combine ecological restoration and water storage	increase water storage capacity		1	1			1			1
M019	Rehabilitate floodplains	floodplain restoration		1	1			1	1	1	
M020	Management of storm water	increase water retention capacity			1	1		1			1
M021	Controlled drainage	increase water storage capacity			1	1		1			1
M022	Modification of the excess water drainage system (more local retention or reservoirs)	increase water storage capacity			1	1		1			1
M023	Construct small reservoirs in hilly regions	increase water retention capacity			1	1		1			1
M024	Enlargement of floodplains	floodplain restoration		1	1			1	1	1	
M025	Planned inundations of protected (former natural) floodplains	floodplain restoration		1	1			1	1	1	
M026	More space for rivers (enlarging floodplains)	floodplain restoration		1	1			1	1	1	
M027	Establish new retention areas	increase water retention capacity			1	1		1			1
M028	Flood protection (dykes, etc.).	negative									
M029	Forest restoration	reforestation		1	1	1		1		1	
M030	Wetlands	floodplain restoration		1	1	1		1	1	1	
M031	Wetlands	floodplain restoration		1	1	1		1	1	1	
M032	Restoration of wetlands	floodplain restoration		1	1	1		1	1	1	

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M033	Land use planning		1	1			1			1	
M034	Reforestation	reforestation		1	1	1		1		1	
M035	Reallocation of farm land (exchange of land for more economical management)		1	1			1			1	
M036	Establish natural course of rivers	channel shape restoration			1	1		1	1	1	
M037	Wetlands	floodplain restoration		1	1	1		1	1	1	
M038	Restoration of wetlands	floodplain restoration		1	1	1		1	1	1	
M039	Keeping forest with birch and fern	outside scope									
M040	Considering legal regulations when destroying unused stocks of pesticides; Establishing legal import of pesticides and reporting of imports to inspection		1				1			1	
M041	Priority given to drinking water		1				1			1	
M042	Establish regional drinking water supply systems		1	1			1			1	
M043	Technology for improving drinking water quality in the case of uncertain groundwater resource.	outside scope									
M044	Water pricing	outside scope									
M045	Modifications to water regulation practices e.g. smaller variations on water levels.	flow restoration		1	1	1		1	1		1
M046	Initiating self dynamic processes of river morphology development in densely populated regions.	channel shape restoration		1	1				1	1	
M047	Increase of saltwater-freshwater connections for the benefit of fish migration.				1	1			1	1	
M048	Hydromorphological measures for improving ecological status.	channel shape restoration		1	1	1		1	1	1	1
M049	General improvement of stream morphology	channel shape restoration		1	1	1		1	1	1	1
M050	Regulations raising the lowest water levels of lakes in Spring time	increase water retention capacity				1		1			1
M051	Robust rehabilitation measures and hydromorphological measures e.g. meandering streams and ecological designed banks.	channel shape restoration			1	1		1	1	1	1

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M052	Measures to increase ecological connections	improve connectivity		1	1	1			1		1
M053	River restoration	channel shape restoration			1	1		1	1	1	1
M054	Modify some infrastructure, e.g. dams overhighing	increase water storage capacity		1	1	1		1			1
M055	Remove flood walls	floodplain restoration			1	1			1		1
M056	Improvement of river structures	channel shape restoration, habitat restoration				1			1		1
M057	Measures to improve potential migration of fish species	improve connectivity		1	1	1			1		1
M058	Water level management in lakes during periods of low precipitation	outside scope									
M059	Robust rehabilitation and hydromorphological measures like meandering streams and ecological designed banks.	channel shape restoration			1	1		1	1	1	1
M060	Measures to increase ecological connections	channel shape restoration		1	1	1			1		1
M061	River restoration	channel shape restoration			1	1		1	1	1	1
M062	Develop environmental flow in regulated rivers	flow restoration		1	1	1		1	1	1	1
M063	Build fish passage or elevator at lateral structures	improve connectivity		1	1	1			1		1
M064	Restore hydromorphological features	channel shape restoration			1	1		1	1	1	1
M065	Planting of natural riparian tree vegetation along water courses.	riparian/buffer zone restoration			1	1		1			1
M066	Agricultural land uses e.g. catch crops, organic farming		1				1			1	
M067	Buffer zones on agricultural land	riparian/buffer zone restoration			1	1		1			1
M068	Retention of water by changing agricultural techniques (deep ploughing)	increase water retention capacity		1	1			1		1	
M069	De-eutrophication measures	nutrient load reduction	1	1			1	1		1	
M070	Winter hardy catch crops, late ploughing	nutrient load reduction	1	1	1	1	1	1		1	

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M071	Erosion control measures	sediment load reduction		1	1	1		1		1	
M072	Catch crops	nutrient load reduction	1	1	1	1	1	1		1	
M073	Optimal use of fertilisers	nutrient load reduction	1	1	1	1	1	1		1	
M074	Manure management	nutrient load reduction	1	1	1	1	1	1		1	
M075	Increase vegetation coverage on arable land in winter	nutrient load reduction	1	1	1	1	1	1		1	
M076	Decrease of erosion by adapted good practice	nutrient load reduction	1	1	1	1	1	1		1	
M077	De-eutrophication measures	nutrient load reduction	1	1			1	1		1	
M078	Measures to control non-point source pollution	nutrient load reduction	1	1			1	1		1	
M079	Manure management	nutrient load reduction	1	1	1	1	1	1		1	
M080	Limits on fertiliser inputs	nutrient load reduction	1	1			1	1		1	
M081	Optimal use of fertilisers	nutrient load reduction	1	1	1	1	1	1		1	
M082	Catch crops with normal ploughing	nutrient load reduction	1	1	1	1	1	1		1	
M083	Buffer strips between agricultural land and surface water bodies	riparian/buffer zone restoration			1	1		1			1
M084	Development of water recovery (recycling, infiltration, etc.)	outside scope									
M085	Development of water saving	outside scope									
M086	Influence water use for the reduction of water needs	outside scope									
M087	Various measures to promote sustainable water use (surface water & groundwater)	outside scope									
M088	Prioritised water use	outside scope									
M089	Implementation of the safety water technologies	outside scope									
M090	Renovate supply pipes	outside scope									

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M091	Mulching	increase water retention capacity		1	1	1		1		1	
M092	Conservation tillage	increase water retention capacity		1	1	1		1		1	
M093	Night-time irrigation	increase water retention capacity		1	1	1		1		1	
M094	Improved varieties and cleaning of dirty/saline water	outside scope									
M095	Use irrigation to save water for later use	increase water retention capacity		1	1	1		1		1	
M096	Agricultural water-metering	outside scope									
M097	Agricultural techniques for water retention	increase water retention capacity		1	1	1		1		1	
M098	Efficient usage & conservation technologies	outside scope									
M099	Water friendly farming – abandonment of turnip, rape, potato etc.	increase water retention capacity		1	1	1		1		1	
M100	Water resource demand management measures	outside scope									
M101	Measures to deal with invasive species, e.g. controls on importation and releases.	invasives	1	1			1	1		1	
M102	Reduce phosphates entering wastewater (e.g. through phasing out of phosphate detergents).	outside scope									
M103	Tune wastewater discharges to the carrying capacity of the aquatic system	nutrient load reduction		1	1			1		1	
M104	Action plan for reducing overflow frequencies	outside scope									
M105	Building of waste water treatment plants for urban wastewaters	nutrient load reduction		1	1			1		1	
M106	Nutrient removal from sewage water	nutrient load reduction		1	1			1		1	
M107	Measures to control point source pollution	nutrient load reduction		1	1	1		1		1	
M108	Building and improvement of waste water treatment plants	nutrient load reduction		1	1			1		1	
M109	Emissions control from waste water treatment plants		1				1			1	

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M110	Measures to deal with nutrient pressures, e.g. licensing discharges from waste water treatment		1				1			1	
M111	Improvement of waste water purification technologies	outside scope									
M112	Best available techniques (BAT) for livestock farms	outside scope									
M113	Research on possibilities of pollution spreading from upper to lower aquifer	outside scope									
M114	Design of new or enhanced wastewater treatment works.	outside scope									
M115	Protection of high altitude wetlands from degradation of catchments, water diversions, unsustainable tourism and other pressures		1				1			1	
M116	Peatland rewetting	increase water retention capacity			1	1		1		1	
M117	Protection of pristine peatlands	outside scope									
M118	Restoration of mangroves	coast									
M119	Landslide hazard mapping (piezometric and other) and early warning systems in areas with low slope stability	outside scope									
M120	Installation of drain systems on hillsides for preventing or remedying landslides	outside scope									
M121	Constructing or raising dikes	outside scope									
M122	abandoning other low-lying areas and relocating to higher ground	outside scope									
M123	Reshaping low-lying cities to a Venice type with a mixture of retreat and protection, using measures such as raising houses on stilts, abandonment and sea walls	outside scope									
M124	Construction of breakwaters - hard structures to absorb wave energy and reduce wave heights along the critical coast areas	coast									
M125	Construction of jetties to protect river outlets from siltation and migration	improve connectivity		1	1	1			1		1
M126	Beach nourishment - depositing sand onto the open beach as well as beach scraping, building artificial dunes as storm buffers and beach sand reservoirs,	coast									
M127	Beach draining - laying pipes underneath the beach to suck in the water and trap sand.	coast									
M128	Constructing of groins - hard structures perpendicular to the coastline, which are used together with beach nourishment to trap sand.	coast									

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M129	Restrict development or prohibit redevelopment of areas prone to flood or land slide hazards	outside scope									
M130	Integrated coastal zone management (ICZM) - complex of measures	coast									
M131	Turning present coastal lowlands to areas for aquaculture	coast									
M132	preserve existing wetlands through engineering (elevating)	coast									
M133	Elevate everything - land, structures, wetlands	coast									
M134	Adaptation measures at waste disposal and storage sites	outside scope									
M135	Adaptation measures at sewage collection and treatment sites	outside scope									
M136	Adaptation measures at mining and mineral extraction sites	outside scope									
M137	sediment retention volumes	sediment load reduction		1	1	1		1		1	
M138	reforestration	reforestation		1	1	1		1		1	
M139	Contour barriers	sediment load reduction		1	1	1		1		1	
M140	backfilling of ravines	outside scope									
M141	construction of terraces on the hills	sediment load reduction		1	1	1		1		1	
M142	Construction and refurbishment of wastewater treatment plants and sewerage systems in conurbations with more than 2,000 PE	nutrient load reduction		1	1			1		1	
M143	Construction and refurbishment of waste water treatment plants and sewerage systems in conurbations with up to 2,000 PE in areas requiring special protection	nutrient load reduction		1	1			1		1	
M144	Construction and refurbishment of waste water treatment plants and sewerage systems in municipalities with up to 2,000 PE	nutrient load reduction		1	1			1		1	
M145	Technical measures regarding industrial polluters (removal of especially dangerous harmful substances)	toxic load reduction		1	1			1		1	
M146	Revitalization of minor watercourses and small areas in municipalities	stream restoration		1	1	1		1		1	
M147	Old environmental loads	toxic/nutrient load reduction		1	1			1		1	

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M148	Revitalization of watercourses and inappropriate drainage, improvement of watercourse passability	increase water storage capacity, improve connectivity, stream restoration		1	1	1		1		1	
M149	Implementation of land consolidation measures and comprehensive land consolidation measures (erosion reduction, improvement of the ecological stability of landscape)	sediment load reduction		1	1	1		1		1	
M150	Riparian stand establishment and rehabilitation	riparian/buffer zone restoration			1	1		1			1
M151	Grassing of arable land, in particular along watercourses	sediment load reduction			1	1		1		1	
M152	Improvement of tree species and spatial composition of forests in especially protected areas	outside scope									
M153	Afforestation of farmland	reforestation		1	1	1		1		1	
M154	Improvement of tree species composition of forest stand	outside scope									
M155	Technical and biological measures to reduce euthropication of surface water	nutrient load reduction		1	1			1		1	
M156	Grassland management	outside scope									
M157	Complex monitoring, identification and assessment of the status of water quality and quantity (Complex monitoring of water)	outside scope									
M158	Environmental educational programmes and provision of environmental consulting		1				1				
M159	Improvement of human resources potential in the field of agriculture (landscape maintenance and protection of the environment, soil erosion, water pollution, improvement of biodiversity etc.)		1				1				
M160	Reduction of surface water and groundwater pollution from agricultural sources	nutrient/organic/toxic load reduction		1	1	1		1		1	
M161	Measures to reduce runoff from the watershed	flow restoration		1	1			1		1	
M162	Building of polders larger than 50 thousand square meters	outside scope									
M163	Regulation of watercourse channels in municipal built-up areas in a nature-friendly manner	negative									

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M164	Improvement of landscape retention capacity and reduction of flood occurrence in a nature-friendly manner	increase water retention capacity		1	1			1		1	
M165	Erosion protection and reduction of adverse impacts of surface water runoff	sediment load reduction		1	1	1		1		1	
M166	Flood protection measures with retention	flow restoration		1	1			1		1	
M167	Flood protection measures along watercourses	negative									
M168	Improvement of safety of hydraulic structures	negative									
M169	Studies on rainfall-runoff conditions and specification of flood plain areas	outside scope									
M170	Fish ponds rehabilitation, refurbishment, and sludge removal, and construction of water reservoirs	nutrient/organic load reduction				1			1		1
M171	Flood protection measures implemented as a part of land consolidation	negative									
M172	Implementation of precautionary flood protection measures on minor watercourses and in their basins and erosion protection measures on forest land, repairs of bank scours, erosion scours and damming, stabilization of ravines on land designed to play the role of a forest.	outside scope									
M173	Development and modernization of information systems of the flood forecasting and warning service	outside scope									
M174	Support of processing the mapping data about flood hazard and flood risk	outside scope									
M175	Construction and rehabilitation of water treatment plants and drinking water resources in municipalities with more than 2,000 inhabitants	nutrient load reduction		1	1			1		1	
M176	Construction and rehabilitation of water conduits and water distribution networks in conurbations with more than 2,000 inhabitants	nutrient load reduction		1	1			1		1	
M177	Construction and rehabilitation of water treatment plants and drinking water resources, and construction and rehabilitation of water conduits and water distribution networks in conurbations with up to 2 000 inhabitants in areas requiring special protection	nutrient load reduction		1	1			1		1	
M178	Construction and rehabilitation of drinking water supply systems in municipalities with up to 2,000 inhabitants	nutrient load reduction		1	1			1		1	
M179	Prospecting for and exploiting new groundwater resources to supply water to the population	negative									

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M180	Geological and hydrogeological works for the purpose of re-evaluating the groundwater resources for water supply to the population	negative									
M181	Prospecting for, survey and assessment of the possibilities of controlled groundwater recharge by surface water (artificial groundwater recharge) from watercourses or reservoirs	outside scope									
M182	Need of action in small catchments for which the risk of convective heavy rainfalls (thunderstorms) has been indicated	outside scope									
M183	Protect the remaining retention areas to minimize the peak flow of small-scale, convective heavy rainfalls.	flow restoration									
M184	Measures to mitigate the expected higher input of nutrients from the soil erosion and flooding of the dung depositories	nutrient load reduction				1		1		1	
M185	Compensatory measures such as Irrigation systems	negative									
M186	Water-saving measures (particularly in the agricultural irrigation)		1				1			1	
M187	Increase available water supply through increased water retention in the area	increase water retention capacity		1	1			1		1	
M188	Artificial groundwater recharge and storage	increase water storage capacity		1	1			1		1	
M189	Broader insuring of drinking water supplies by regional and interregional loop lines	outside scope									
M190	Measures to meet the feed requirement for livestock in dry periods	outside scope									
M191	Creation of special drought management plans		1	1			1				
M192	Increase cleaning efficiency of sewage treatment plants and combined sewers or discharges from storm water channels, because of the lower dilution capacity in receiving waters as a consequence of low flow and increased water temperatures	nutrient/organic load reduction				1			1	1	
M193	Adjusting reference conditions and setting the quality objectives in some water body types.	outside scope	1				1				
M194	Develop norms for snowmaking reservoirs in order to avoid further deterioration of water scarcity by additional withdrawals.	outside scope	1				1				
M195	More attention to the stability of the increasing dams and the environmentally friendly operation of the plants.	outside scope									
M196	Maintain the continuous long-term measurement network for the observation of various climate factors and their impact on the water balance.	outside scope									

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M197	Ensure that it is the middle and higher elevations, for which the worse and very different impacts of climate change have been projected, would be adequately monitored.	outside scope									
M198	Estimate future needs in drinking water supply, greywater treatment, and water supply for industry and agriculture (taking into account the impact of Climate Change)	outside scope									
M199	Scenario development for predicted long term water quantity changes (taking into account the effects of climate change)	outside scope									
M200	Determination of the quantitative capacity of water (taking into account the impact of climate change)	outside scope									
M201	additional measures to first retain water for later slow release	increase water retention capacity		1	1			1		1	
M202	mapping of flood zones	outside scope									
M203	implementation of urban constraints, promoting agri-environment (hedges, headlands, ...)	outside scope									
M204	maintenance of the integrity of rivers	outside scope									
M205	Carrying out remedial works or the local improvement of flood warning.	outside scope									
M206	conduct investigative monitoring of the effects of climate change and the impact of invasive species on aquatic biota and sediments in sensitive and vulnerable areas and areas for fish and shellfish.	outside scope									
M207	Study climate change impact on water resources, ecosystems, ecological status, crops and hydropower. Designation of sensitive areas and Indicators	outside scope									
M208	Assess the medium and long term need for water in different economic sectors (households, agriculture farm economy and hydropower) and availability of the necessary water resources. Determine problematic sectors and areas.	outside scope									
M209	Establish a system for assessing Impact of climate change, monitoring and indicators.	outside scope									
M210	Assessment of the economic impact of climate change on different economic sectors and development forecasts scenarios in the context of climate change, determining the economic Indicators.	outside scope									
M211	Studies to reassess the needs of water and effective management of the resource optimization of the transferred quantities in other river basins	outside scope									

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M212	Development of methodology for determining the fiscal incentives for the introduction of mechanisms and practices for water efficiency.	outside scope									
M213	Development of management plans water resources in drought conditions	outside scope									
M214	Modernization of the network meteorological and hydrological monitoring to obtain more and more reliable data for water resource	outside scope									
M215	Study river topography and create a digital altitude model	outside scope									
M216	Mapping of flood zones	outside scope									
M217	Establishment of hydrological models for water management	outside scope									
M218	Identify areas threatened by flooding under different scenarios for flood height.	outside scope									
M219	Development of methodology for assessing damage and assess the potential damage of flood risk areas	outside scope									
M220	Improve hydromorphological condition of wetlands to achieve good water status and protection against high floods	increase water storage capacity									
M221	Establishment of an early warning system for flood risk	outside scope									
M222	Training for use of the early warning system	outside scope									
M223	Training and information campaigns for problems associated with floods	outside scope									
M224	Consulting the public on determining risk areas	outside scope									
M225	Consulting the public on development of flood prevention measures	outside scope									
M226	Informing the public regarding developed measures	outside scope									
M227	Establishment of a mechanism to coordinate actions in cases of flood risk.	outside scope									
M228	Creation of a coordination mechanism for flood occasions	outside scope									
M229	Maintenance of river beds to ensure the passage of the flood peak.	flow restoration		1	1			1			1
M230	Additional runoff regulation	increase water storage capacity		1	1	1		1			1

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M231	Conservation or plumbing of unused drill holes	outside scope									
M232	Prevent overexploitation of groundwater	outside scope									
M233	Assessment and prediction of changes of water resources based on data from water monitoring	outside scope									
M234	Reforestation of clear cutting areas in water supply zones, avoiding acacia and poplar	reforestation		1	1	1		1		1	
M235	Improving forest management in water supply zones	outside scope									
M236	Anti-erosion measures and reduction of unused water flow	sediment load reduction		1	1	1		1		1	
M237	Planting appropriate native tree species	reforestation			1	1		1		1	
M238	Prevention of forest fires	outside scope									
M239	Providing economical water use by building water supply systems	outside scope									
M240	Using economic regulators, leading to water saving in areas with a shortage of water resources	outside scope									
M241	Prohibition on empting small dams for fishing purposes		1				1				
M242	Stimulating the economic use of water for irrigation	outside scope									
M243	Regular informing of the public about the state of water resources of the country at local and national level	outside scope									
M244	Public control over water pollution and illegal abstraction and creating “green line” phones to municipalities and regional Inspectorates of environment and water	outside scope									
M245	Develop fiscal incentives for the introduction of mechanisms and practices for water efficiency	outside scope									
M246	Reduce losses in water supply network through rehabilitation or construction of new pipelines	outside scope									
M247	Prohibition on issuing permits for water, where the total water use exceeds the operational resources of groundwater bodies	outside scope									
M248	Control permits for water (control abstraction)	outside scope									
M249	Regulation in the permits for water abstraction for dangerous lowering of groundwater levels	outside scope									

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M250	Prohibition on issuing permits for water for bodies of groundwater-dependent Intermittent rivers	outside scope									
M251	Prohibition on issuing permits for construction of protective facilities of surface water in areas where it might significantly increase groundwater levels	outside scope									
M252	Construction of reservoirs to regulate the maximum (peak) flows	flow restoration		1	1	1		1			1
M253	Maintenance of water supply networks in good condition	outside scope									
M254	Optimization of water abstraction for industrial use through the introduction of closed cycles	increase water storage capacity			1	1		1		1	
M255	Control of compliance with permit conditions for water use	outside scope									
M256	Monitoring of surface and groundwater to assess the condition of water bodies	outside scope									
M257	Application of environmental standards in production processes	outside scope									
M258	Regulation for the permits for construction and operation of new and existing industrial installations and facilities	outside scope									
M259	Control over the conditions in the permits issued	outside scope									
M260	Regulation to assess the environmental impact assessment (EIA) of investment proposals for construction, operations and technology according to EPA	outside scope									
M261	Regulation to assess the need for an EIA according to EPA	outside scope									
M262	Control over fulfilment of the conditions of the EIA decisions	outside scope									
M263	Preparation of Management Plan for flood risk	outside scope									
M264	Leave more storage capacity for winter in the regulated lakes in southern and central Finland because of increasing winter runoff and more frequent winter floods	management									
M265	Need for lower storage capacity in spring when the snowmelt floods will disappear or be reduced	management									
M266	Need to fill the lakes in spring because of longer and sometimes also drier summers	management									
M267	Continuing need for the storage capacity in northern Finland to reduce the flood risk caused by snowmelt	management									
M268	Need to change more than half of the current 220 lake regulation permits	management									

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M269	With increasing traffic volume increases the risk of accidents and groundwater protection should be strengthened	outside scope									
M270	Creating flood hazard maps	outside scope									
M271	Keeping the extremely flood prone areas free of buildings	outside scope									
M272	Flood-adaptation of buildings in areas of low flood hazard	outside scope									
M273	Basing flood forecasting on a long-term cross-border cooperation between competent authorities with the involvement of scientific research.	outside scope									
M274	Foundation of Flood Partnerships of communities exposed to a comparable flood hazards with the aim to better inform the local population of flood hazards and to improve flood protection and flood prevention.	outside scope									
M275	Optimizing the transboundary flood forecasting system in the Moselle catchment area	outside scope									
M276	Establishment of a competence center providing information and advice to communities on construction precautions	outside scope									
M277	Determine the impact of climate change on high and low water conditions in the Mosel basin.	outside scope									
M278	Establishment of rules for the minimum residual flows at hydropower plants	outside scope									
M279	Limit unsustainable water uses that are more common in the summer months and those which cannot and should not be considered in dimensioning of water supply infrastructure.	outside scope									
M280	Planning new development areas with stormwater and sewage water separation systems and remote retention reservoirs	outside scope									
M281	Development and formulation indicator and monitoring systems to follow climate change impacts on hydrology and water management, preparation of impact assessment studies	outside scope									
M282	Assessment of the real constraints and potential for adaptation with special regards to utilisable water reserves and flood control	outside scope									
M283	Development of economic water usage, higher involvement of local water assets and precipitation	outside scope									
M284	Repeated measuring and assessing of water restraint potentials and surface and groundwater reserves	outside scope									

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M285	Mandatory development of detailed climate change related impact assessment for significant hydrological investments	outside scope									
M286	Reduction of non-climate related impacts on hydrological reserves (land use, urbanisation, settlement policy, wastewater)	outside scope									
M287	Quantitative and qualitative assessment of water reserves trends, as well as water demand and supply trends has to be undertaken in order to ensure the security of underground water management	outside scope									
M288	Assessment of climate change impacts on the natural status of surface and underground waters	outside scope									
M289	Impact assessment for water catchment areas and development of indicator system for monitoring changes in the natural waters.	outside scope									
M290	Develop a new water resources management (drought tolerant plants, water-saving irrigation technologies and equipment), apply water saving methods to increase the efficiency of water use,	outside scope									
M291	Replace the fast water runoff based approach by rainfall floods retention, which appears in both the floods and droughts risk management plans and measures	increase water retention capacity		1	1			1		1	
M292	Treated waste water should be kept on site	nutrient/organic load reduction				1			1	1	
M293	The decline of the dilution capacity due to low water in streams should be taken into account in waste water discharge into natural recipients	outside scope									
M294	The flood water management must be approximated to natural regimes; the RBMP morphological measures in the floodplains should targeted at flood formation, in part, restoration of the floodplain and ecological aspects with a flexibility for the treatment of extreme floods	outside scope									
M295	Restoration of wetlands to ensure their water-holding capacity, local water supply and to protect the ecosystems	increase water storage capacity			1	1		1		1	
M296	The impact of climate change induced low water supplies can be markedly reduced by increasing the storage capacity. The role of water storage for water resource management is expected to increase, while the construction and operating of the storage capacities must take into account the WFD ecological prescriptions. (Chapter 8.4.3)	increase water storage capacity			1	1		1		1	
M297	Altered abstraction timing	outside scope									
M298	Create buffers around water bodies	riparian/buffer zone			1	1		1			1

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
		restoration									
M299	Connection of unsewered wastewater discharges to municipal system in selected areas where assimilative capacity is available during low flow	nutrient/organic load reduction				1			1	1	
M300	Water conservation measures		1				1				
M301	Actions may be required to replace habitat lost through sea level rise or increased flooding	outside scope									
M302	Projects to assess the impacts of climate change.	outside scope									
M303	Make provision for pre-treatment requirements for industrial wastewater entering the collection systems and treatment plants considering the potentially reduced assimilative capacity in rivers in summer	toxic load reduction				1			1	1	
M304	Monitor changes in hydrological pressures and review and adjust abstractions and other pressures which reduce groundwater levels in protected areas for groundwater dependent and/or supported habitats and species.	outside scope									
M305	Actions to reduce erosion and sedimentation pressures should be able to meet increased risk of extreme events. Consider potential for habitat creation in managed retreat from rising sea level	sediment load reduction		1	1	1		1		1	
M306	Increase the efficiency of water use in the context of reducing river low flows in summer, supported by metering, leakage control and potential water harvesting.	outside scope									
M307	Adaptation measures addressing reduction of habitat fragmentation, protection and restoration of floodplains and wetlands at high-status sites and protected areas for water dependent habitats and species	improve connectivity	1	1			1	1		1	
M308	Adaptation measures addressing changes to ground and surface water flow regime at high-status sites and protected areas for water dependent habitats and species	flow restoration	1	1			1	1		1	
M309	Adaptation measures addressing changes to erosion and sedimentation pressures at high-status sites and protected areas for water dependent habitats and species	sediment load reduction	1	1			1	1		1	
M310	Adaptation measures addressing changes to diffuse and point source nutrient loadings at high-status sites and protected areas for water dependent habitats and species	nutrient/organic load reduction	1	1			1	1		1	
M311	Addressed the decrease in assimilative capacity of water bodies receiving pollutant loads from point and non-point sources.	?									
M312	Prepare for certain physical modifications in addition to the ‘soft’ flood management systems under ‘Catchment Flood Risk Management Plans’, in order to manage	outside scope									

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
	extreme events, rising sea levels and storm surges.										
M313	Measures to maintain compensation flows at reduced available water resources in summer to contribute to fish migration within systems particularly around or across barriers such as weirs.	improve connectivity		1	1	1		1			1
M314	Water capturing during peak flows of extreme rainfall events, and off-channel storage to reduce flood hazard and increase storage infrastructure.	flow restoration		1	1	1		1			1
M315	Consider the need for additional storage infrastructure to compensate for seasonal impacts of climate change on river flows.	outside scope									
M316	Planning of the district-scale water balance, with identification of critical and quantitative measures to reduce incidence and intensity and for the maintenance and / or improvement of the status of surface water bodies	outside scope									
M317	Extending the application of agri-environment measures of the Rural Development Plans imlying further action and / or interventions aimed specifically at the WFD objectives	outside scope									
M318	Redefining and adapting the Programme of Measures to the climate change scenarios in the Po Basin	outside scope									
M319	Creating resource conservation plans for the various uses for hydrographically homogeneous areas at subbasin level	outside scope									
M320	Downscaling of the global and European climate scenarios to the Po river basin and evaluation of the impacts on the current measures for flood protection and water resources management	outside scope									
M321	Development of a support tool for the simulation of scenarios water use in agriculture and alignment of agro-meteorological forecasts with the management of water resources	outside scope									
M322	Advancing knowledge on the relationships between climatic variations and mechanisms of groundwater circulation	outside scope									
M323	Accelerate the implementation of strategies to climate change, as adjusted for Po basin	outside scope									
M324	Measures defined on the basis of monitoring the progress and effectiveness of the RBM Plan and the results of monitoring carried out for the ongoing SEA	outside scope									
M325	Estimate the potential effects of climate change on water resources of the basin (according to the scenario hypothesis of water shortage). The main factors affecting water resources will be the reduction in rainfall and the increased evaporation	outside scope									

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
	losses from the catchment.										
M326	Increases the resilience of ecosystems to the impacts of climate change	outside scope									
M327	Continue controls on importation and releases of invasive non-native species.	outside scope									
M328	Consider broadening the range of species restricted for importation	outside scope									
M329	Develop the 'landscape ecology approach' to identify and protect key habitats, open up new habitats and develop and maintain wildlife corridors. Reduce habitat fragmentation and protect and restore areas of floodplains and wetlands.	outside scope									
M330	Map current and future climate spaces and the vulnerability and impacts for priority species and environments.	outside scope									
M331	Reduce water demand	outside scope									
M332	Change timing of abstraction		1				1			1	
M333	Provide water supply from other sources	outside scope									
M334	Control pollution load at source	nutrient/organic load reduction	1				1			1	
M335	Capture polluted runoff from steadings (eg in constructed farm wetlands);	nutrient/organic/toxic load reduction			1	1		1			1
M336	reduce pollutant content of sewage at source	nutrient/organic/toxic load reduction			1	1		1			1
M337	Improve sewer network; increase treatment	outside scope									
M338	separate out rainwater run-off	increase water retention capacity		1	1			1		1	
M339	Reduced inputs into surface waters from land contaminated by mine spoil tips	toxic load reduction		1	1	1	1	1		1	
M340	Treat discharges from abandoned mines	toxic load reduction		1	1	1	1	1		1	
M341	sustainable urban drainage systems	increase water retention capacity		1	1			1		1	
M342	treat highly polluting urban discharges	nutrient/organic/toxic load reduction			1	1		1			1

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M343	reduce inputs into drains	increase water retention capacity		1	1			1		1	
M344	Reduce inputs of nutrients into lochs	nutrient load reduction			1	1		1		1	
M345	control sea lice infestations at marine cage sites	coast									
M346	Provide improved river flows by integrated operation of scheme; changing pattern of abstraction	flow restoration		1	1			1		1	
M347	Provide improved river flows by reducing net abstraction	flow restoration		1	1			1		1	
M348	Reduce leakage rates in water supply network	outside scope									
M349	Increase water use efficiency	outside scope									
M350	Increase supply capacity	outside scope									
M351	improve bank and shore vegetation	riparian/buffer zone restoration			1	1		1			1
M352	Re-engineer more natural bed and bank features (eg recreate meanders in straightened rivers)	channel shape restoration			1	1		1	1	1	1
M353	Modify, reduce or cease maintenance works (eg dredging)	reduce direct human interference			1	1		1	1		1
M354	Move embankments further away from banks and shores; reduce pressures from hard engineering structures on beds, banks and shores (eg improve design, use softer engineering techniques, remove)	floodplain restoration		1	1			1			1
M355	Install fish passes	improve connectivity		1	1	1		1			1
M356	Remove nonoperational dams, weirs and other structures	improve connectivity		1	1	1		1			1
M357	Exploration of the impact on climate change and drought on drought-sensitive nature and including the results in the national survey of fresh water	outside scope									
M358	Exploration of the impact on climate change on water transport	outside scope									
M359	Exploration of the impact on climate change on drinking water supply	outside scope									
M360	Gradually broaden the North Sea coast with sand nourishments spread out over a hundred years to allow nature to develop	coast									

			Scale				Type			Source or effect	
ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M361	Gradually raise the water level in the IJsselmeer by a maximum of 1.5 meters, to insure the capability of releasing excess water without having to pump	outside scope									
M362	protect the Rijn estuary region on both the sea-side and river-side with movable flood barriers	outside scope									
M363	provide flood areas for excess riverwater from the Maas and Rijn in the Krammer-Volkerak, the Zoommeer, the Grevelingen and possibly the Oosterschelde	outside scope									
M364	Increase the lifespan of the Oosterschelde flood barrier; it is now made to work till 2075	coast									
M365	Stregthen and raise sea and river dikes	outside scope									
M366	Keep the Westerschelde and New Waterway open	coast									
M367	Investigate the impact of dumping sand on the beach or forebanks during sand nourishments on beach ecosystems	coast									
M368	Enhance the re-colonization potential of species;	outside scope									
M369	Improve the connectivity of river systems;	improve connectivity		1	1	1		1			1
M370	Creat buffer strips, which reduce nutrient loads of lakes and rivers and also offer shading of water;	riparian/buffer zone restoration			1	1		1			1
M371	Carry out targeted investigations on the effect of climate change on species.	outside scope									
M372	Turning ravines into ponds	outside scope									
M373	Growing biofuel crops on arable lands	outside scope									
M374	Desalination of brackish groundwater	outside scope									
M375	Using natural wetlands for tertiary treatment	negative									
M376	Peak runoff control in peatland forestry	increase water storage capacity			1	1		1		1	
M377	Smart Flow sewer to separate the most polluted water of the first rainfall after a dry period.	outside scope									
M378	Peatland restoration and peat rewetting	increase water storage capacity			1	1		1		1	
M379	sediment removal from shallow lakes	increase water storage			1	1		1		1	

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		capacity, nutrient/organic/toxic load reduction									
M380	Creating riparian shading at small and moderate-size watercourses to control excessive algal growth during summer periods	riparian/buffer zone restoration			1	1		1			1
M381	Planting large shade trees on the dikes	riparian/buffer zone restoration			1	1		1			1
M382	Restoration of streambank vegetation for temperature control	riparian/buffer zone restoration			1	1		1			1
M383	Retaining forested buffers along stream banks in logging areas	riparian/buffer zone restoration			1	1		1			1
M384	grass filters and creation of mini-paddy fields in combination with forest buffer	nutrient/organic load reduction	1				1			1	
M385	In-stream salmonid habitat restoration techniques with turbulence generated when water flows over weirs into plunge pools, or merely surface agitation from flow constriction	habitat restoration				1			1		1
M386	trash dam removal to facilitate either fish passage and/or land drainage	improve connectivity				1		1			1
M387	management of the riparian zone to prevent overshading	negative									
M388	Fencing and the protection of riparian vegetation	riparian/buffer zone restoration			1	1		1			1
M389	Channel modification using riparian structures	riparian/buffer zone restoration			1	1		1			1
M390	Increasing river flow to control phytoplankton standing stock in rivers	negative									
M391	Clearcutting to increase water yield to streams and reservoirs during periods of low flows	negative									
M392	Silvicultural measures to protect against reductions in low flow levels during the next rotation ((1) reducing stand stocking to below 70% relative density; (2) using short cutting cycles; (3) using short rotations; (4) encouraging hardwood species; (5) encouraging regeneration from seedlings rather than sprouts; and avoiding conversion to softwood species from hardwood species.	increase water storage capacity		1	1			1		1	
M393	Silvicultural measures to limit peak (flood) flows by (1) maximizing stand stocking and maintaining it above 70% relative density; (2) using long cutting cycles; (3)	increase water storage capacity		1	1			1		1	

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	using long rotations; (4) encouraging conifer species; and maintaining less than 25% of the area in openings or trees less than 10 years old.										
M394	Silvicultural measures to restore hydrologic function to previously disturbed lands by maximizing leaf litter and coarse woody debris, and slowing the decomposition rate.	increase water storage capacity		1	1			1		1	
M395	Enhance habitat for warmwater fish by (1) maintaining buffer strips; (2) removing some trees to allow more sunlight to reach the water surface; (3) allowing a few mature trees to die in place; and (4) prohibiting livestock from entering the buffer strip.	riparian/buffer zone restoration			1	1		1			1
M396	Treatments for enhancing cold-water fish habitat by (1) maintaining buffer strips with at least 70% relative density; (2) allowing a few mature trees to die in place; and (3) creating small penings less than 0.1 ha in size.	riparian/buffer zone restoration			1	1		1			1
M397	Measures of intensive protection for riparian areas by (1) maintaining buffer strips with at least 70% relative density; (2) allowing a few mature trees to die in place; and (3) creating small openings less than 0.1 ha in size.	riparian/buffer zone restoration			1	1		1			1
M398	Forestry measures to provide intensive protection for water quality by (1) maintaining extra wide buffer strips; (2) maintaining plant cover at all times; (3) encouraging rapid establishment of regeneration following treatments; (4) minimizing disturbance, erosion, and sedimentation; (5) restricting use of chemicals; (6) restricting road building or use; and (7) restricting beaver activity	riparian/buffer zone restoration			1	1		1			1
M399	Crop residue management CRM. A yearround conservation system that usually involves a reduction in the number of passes over the field with tillage implements andror in the intensity of tillage operations, including the elimination of plowing inversion of the surface layer of soil.	sediment load reduction			1	1		1		1	
M400	Conservation tillage. Any tillage and planting system that maintains at least 30% of the soil surface covered by residue after planting to reduce soil erosion by water.	sediment load reduction			1	1		1		1	
M401	Reduce forest loggings in coastal and high mountain catchments to collect fog and cloud drip as canopy interception gain	increase water storage capacity		1	1			1		1	
M402	Flexible abstraction rules with a higher prescribed flow (PF) at times and in locations where fish are migrating, and a relaxation at other times of year when no migration	flow restoration		1	1			1			1
M403	Abstraction operating rules allowing only a proportion,typically 50%, of the flow above the prescribed flow (PF) to be taken	flow restoration		1	1			1			1
M404	Maintain compensation flows at dam reservoirs	flow restoration			1			1			1

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M405	Releases from dam reservoirs to stimulate upstream migration of adult salmon and sea trout or downstream migration of smolts, to provide flushing flows to clean gravels prior to the spawning season	improve connectivity				1		1			1
M406	Adjust release patterns from hydroelectric power plants to simulate a natural spate hydrograph for the river	flow restoration			1			1			1
M407	Designing a two-stage channel to reinstate favourable velocity and depth conditions below a dam resevoir. The low flow channel will carry compensation flows and normal regulation releases, and a higher level channel over shallow side berms will carry high flows.	flow restoration			1			1			1
M408	Manipulating fluvial erosion by incorporating structures such as live trees, dead trunks and brushwood into the riparian zone.	flow restoration			1			1			1
M409	Monitor and report changes across networks of data-rich or sentinel sites/ hot spots/ indicators/ taxa (e.g., spring-heads, headwater streams, downstream migration of habitats, coastal ditches, freshwater fen/coastal grazing marsh close to tidal limit, wet heath land, amphibians, habitat specialists, glacial relict species, dragonflies, juvenile salmonids, roach and trout [for endocrine disruption], aquatic bryophytes, shallow eutrophic and mesotrophic lakes, and process-based indicators);	outside scope									
M410	Monitor across a range of spatial scales to improve understanding of macro-scale linkages between climate change, fluvial geomorphology and habitat availability;	outside scope									
M411	Undertake data archaeology campaigns to catalogue and digitize paper archives;	outside scope									
M412	Automate trapping and record emergence patterns and timing of aquatic insects (including small streams and standing waters);	outside scope									
M413	Normalize (short) observational records (e.g., eel, salmon, trout, invertebrate populations) for multi-annual and multidecadal variability linked to large-scale ocean (SSTs, AMO) and atmospheric changes (NAO) across NW Europe;	outside scope									
M414	Undertake meta-analysis of data-holdings (by location), centralise and share key temporal and geographical data sets across Europe, plus develop tools to visualize relationships within and between rich data sets;	outside scope									
M415	Review “fitness” of national monitoring and reporting programmes for detecting and attributing climate change impacts (in terms of indices used, spatial/habitat coverage, and temporal sampling regime)	outside scope									
M416	Design harmonized monitoring programmes for research, management and regulation to achieve closer integration and efficiency gains.	outside scope									

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
M417	Co-locate meteorological, environmental and ecological monitoring to track whole ecosystem/community change (at patch,microcosm, river basin scales), including phenology (e.g., timing and duration of salmonid egg and early life stage development, and emergence mismatch), predation, pathogens, and invasive competitors in relation to climate change and other anthropogenic stressors;	outside scope									
M418	Assess risks from synergies between endocrine disruption and temperature-determined gender modification, or remobilisation/ re-deposition/bio-accumulation of toxics substances with more hydrological extreme events;	outside scope									
M419	Assess the consequences of flood and coastal management for freshwaters (fish stocking, floodplain biodiversity, and provision of compensatory habitat);	outside scope									
M420	Model future distributions of invasive species to evaluate different control strategies;	outside scope									
M421	Assess risks posed by tidal stream or wave power structures to (eel and salmonid) fisheries;	outside scope									
M422	Determine relative risks posed by oceanic and freshwater changes to diadromous (e.g., eel larvae) and anadromous species (e.g., salmon growth stage) to assess limits to adaptation.	outside scope									
M423	Establish catchment studies to monitor and model the effectiveness of different configurations of riparian vegetation to control rising water temperature;	outside scope									
M424	Use technologies such as bathymetric LIDAR and aerial photography to map whole catchment fluvial grain size, depths, habitats, barriers (to fish migration or sediment transport) and thermal imaging of low flows (to locate potential sites for plantation of vegetation, thermal refugia within streams);	outside scope									
M425	Collate data and model climate change impacts on groundwater temperature;	outside scope									
M426	Assess the sensitivity of phytoplankton communityto temperature change and co-stressors (such as nutrient loads, lake stratification, and flushing rate);	outside scope									
M427	Review lessons learnt from analogues of climate change (e.g., ecological and habitat responses to temperature regulation by impoundments; reach effects of thermal discharges from power stations; and removal of upland riparian tree cover);	outside scope									
M428	Develop decision-support and regulatory framework for water temperature management based on the above.	outside scope									
M429	Undertake in situ measurement of real-time environmental (flow and temperature) conditions experienced by taxa using tagging and telemetry;	outside scope									

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M430	Develop national evidence base to define critical flow thresholds and habitat quality for target species (or ecosystems);	outside scope									
M431	Collate evidence of the relative efficacy (or detrimental effects) of river flow, water quality and habitat restoration practices in different locations;	outside scope									
M432	Quantify potential impacts of changes in evapotranspiration and CO2 fertilization on minimum river flows and water-table fluctuation in wetlands;	outside scope									
M433	v. Conduct field and laboratory experiments to calibrate uncertain model parameters and processes (e.g., growth and grazing rates of algae);	outside scope									
M434	Model system behaviour to benchmark impacts, then evaluate adaptation options (e.g., bank-side habitat management, compensation flows to maintain habitats and low flows, artificial mixing to reduce Cyanobacteria blooms versus nutrient control, wetland creation, etc);	outside scope									
M435	Model freshwater species and propagule dispersion to evaluate options for improving hydrological connectivity and/or species translocation.	outside scope									
M436	Apply molecular biological techniques to improve understanding of genetic variation (including role of “straying”) as an evolutionary response to direct climate change stressors and habitat changes;	outside scope									
M437	Undertake systematic cataloguing/meta-analysis of the thermal and environmental limits of particular (key-stone) taxa;	outside scope									
M438	Evaluate semi-ubiquitous species' (e.g., mayfly) adaptability through detailed study of their life histories in different places;	outside scope									
M439	Use models to test the assumption that systems with greater heterogeneity and lower levels of habitat disturbance will have greater resilience to climate change (e.g., ecology of ‘natural’ versus engineered channels); Use bioclimatic envelope modelling to identify potential sites for new or re-created freshwater and wetland habitats (as under the Wetland Vision);	outside scope									
M440	Determine societal values, public expectations and willingness to pay when confronted with imminent species and/or habitat loss (e.g., freshwater floodplain fen to brackish fen; and salmonid to non-salmonid river);	outside scope									
M441	Develop visualization tools to convey relative risks arising from climate change and other anthropogenic pressures on the freshwater environment (e.g., new urban and infrastructure development, over-abstraction, saline intrusion, diffuse runoff, uncontrolled waste water discharges, and habitat degradation);	outside scope									
M442	Assess social acceptability of triage for prioritising those species and habitats	outside scope									

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ID number	**Measure**	**adaptation strategy**	**European/ national**	**Catchment**	**sub-cathment**	**Local**	**Legislation/Communication/**	**External measure**	**Internal measure**	**Source or effect**	**Effect**
	considered most worthy of conservation.										
M443	Develop meta-analysis techniques for up-scaling intensively studied sites, river reaches (fluvial geomorphology/ecology) and experimental catchments to regional and national effects;	outside scope									
M444	Integrate mechanistic and bio-climatic space models (by incorporating life history, inter- and intra-specific density dependence, predation, ability to colonise, ecological response to variability and extremes, socio-economic drivers of change, habitat rather than species change, etc);	outside scope									
M445	Conduct field trials for managing water levels, reinstating hydrological connectivity, permeable landscapes, and refuges in ways that limit the spread of invasive species or disease (as in the Usk Valley pilot);	outside scope									
M446	Model conjunctive use of land and water to predict outcomes of best practice forestry, agricultural methods to limit sediment and pollutant delivery, and spatial planning;	outside scope									
M447	Use integrated assessment tools to evaluate possible conflicts and synergies between different adaptation policies (e.g., food security, habitat conservation, and ecosystem service provision);	outside scope									
M448	Use models to assess cost-benefit of habitat restoration, improved water treatment, reduction of agricultural pollution and/or maintenance of flow to prevent exceedance of chemical thresholds (for nutrients and micro-organic compounds);	outside scope									
M449	Use integrated assessment tools to evaluate multi-sectoral trade-offs between adaptation–mitigation–biodiversity (e.g., re-creation of wetlands to manage floods, increase biodiversity and sequester carbon; and low-head hydropower or tidal power affecting emigrating silver eels);	outside scope									
M450	Assess impacts of national food and energy security strategies for freshwaters (such as increased domestic production of fruit and vegetables);	outside scope									
M451	Establish demonstration sites to share best practice, in particular adaptation measures that yield multiple benefits.	outside scope									
M452	Stream channels in riparian restoration projects should be designed narrow enough to overflow into the floodplain on a 1.5 to 2 year timescale	flow restoration			1			1			1
M453	Place bundles of live willow withies behind the trunks at stream shores where they will develop roots and shoots, binding bank material together and trapping silts which act as a growth medium for colonising emergent macrophytes.	habitat restoration									

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M454	Increase stocks of carbon in agricultural systems	outside scope									