European Commission

# NWRM Natural Water Retention Measures

www.nwrm.eu

Service contract n°07.0330/2013/659147/SER/ENV.C1

# Synthesis document n°2

## Biophysical impacts and effectiveness of Natural Water Retention Measures, and their contribution to policy objectives

ACTeon environment research & consultancy

Office International de l'Eau

amec foster wheeler · BEF Latvia · enveco Environmental Economics Consultancy · I.A.CO Ltd Environmental & Water Consultants · imdea water · Regional Environmental Center · REKK · SLU · SRUC

Environment

*This report was prepared by the NWRM project, led by Office International de l'Eau (OIEau), in consortium with Actéon Environment (France), AMEC Foster Wheeler (United Kingdom), BEF (Baltic States), ENVECO (Sweden), IACO (Cyprus/Greece), IMDEA Water (Spain), REC (Hungary/Central & Eastern Europe), REKK inc. (Hungary), SLU (Sweden) and SRUC (UK) under contract 07.0330/2013/659147/SER/ENV.C1 for the Directorate-General for Environment of the European Commission. The information and views set out in this report represent NWRM project's views on the subject matter and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this report. Neither the Commission nor any person acting on the Commission's behalf may be held Key words: Biophysical impact, runoff, water retention, effectiveness - Please consult the NWRM glossary for more information.*

*NWRM project publications are available at*
*http://www.nwrm.eu*

The present synthesis document has been developed in the framework of the DGENV Pilot Project - Atmospheric Precipitation - Protection and efficient use of Fresh Water: Integration of Natural Water Retention Measures (NWRM) in River basin management. The project aimed at developing a knowledge based platform and a community of practice for implementation of NWRM. The knowledge based platform provides three main types of elements:

- the NWRM framework with access to definition and catalogue of NWRM,
- a set of NWRM implementation examples with access to case studies all over Europe,
- and decision support information for NWRM implementation.

For this last, a set of 12 key questions linked to the implementation of Natural Water Retention Measures (NWRM) has been identified, and 12 Synthesis Documents (SD) have been developed. The key questions cover three disciplines deemed important for NWRM implementation: biophysical impacts, socio economic aspects and governance, implementation of financing.

They rely on the detailed delineation of what NWRM cover as described in *SD n°0: Introducing NWRM. Natural Water Retention Measures (NWRM) are multi-functional measures that aim to protect water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes.* Evidences included into these synthesis documents come from the case studies collected within this project (see the catalogue of case studies) and from the individual NWRM factsheets which are available on the page dedicated to each measure (see catalogue of measures). This information has been complemented with a comprehensive literature review.

More information is available on the project website *nwrm.eu*.

**Key words:** Biophysical impacts, ecosystems, groundwater, runoff, infiltration, water cycle, 2020 Biodiversity Adaptation Strategy, Birds Directive, Blueprint, Climate Change Adaptation Strategy, Directorate-General for the Environment (DG ENV), Droughts Directive, Environment Agency (EA), Floods Directive (FD), Green Infrastructure (GI), Habitats Directive, Water Framework Directive (WFD).

Please check the NWRM http://nwrm.eu/glossary

# Table of content

# I. Introduction

To address the current question it is first necessary to understand what the term "biophysical impact" covers. A definition from the University Of Qaran (Source: http://www.e-environment.universityofqaran.com/The%20biophysical%20environment.html) allows us to delineate this: "The biophysical environment is the symbiosis between the physical environment and the biological life forms within the environment, and includes all variables that comprise the Earth's biosphere.

The biophysical environment can be divided into two categories: the natural environment and the built environment with some overlap between the two. Following the industrial revolution the built environment has become an increasingly significant part of the Earth's environment.

The scope of the biophysical environment is all that contained in the biosphere, which is that part of the Earth in which all life occurs. A biophysical environment is the complex of biotic, climatic, and edaphic factors that act upon an organism and determine its form and survival, and morphs itself in the process.

*Ecosystems, of which there are numerous types and are a defined part of the biosphere, collectively make up the whole of the biosphere. Within an ecosystem there are habitats in which an organism including human beings exists.*

*At its most natural state, an environment would lack any effects of human activity, although the scale of this activity is such that all areas of the Earth have had at least some influence by humans.*

*At the other end of the scale is the built environment and in some cases it has the biotic component that is virtually absent.*

*The biophysical environment can vary in scale from microscopic to global in extent."*

In summary, biophysical covers all factors that have an influence on living organisms. When narrowed down to the aquatic environment, and particularly in the context of the Water Framework Directive, these are often referred to as water quality, water quantity and hydromorphology. According to this first definition, biophysical impacts of NWRM could be understood as the positive consequences over biophysical environment (its structure and functions) resulting from well designed and properly implemented measures (that modify water balances in order to make nature work better). It does not mean they do not have negative impacts but by essence, implementing measures is done with as core objective to have positive impacts.

Nonetheless, many NWRM are relevant beyond the aquatic environment, for example potentially being relevant to terrestrial ecology, soils and, in some cases, air quality. Narrowing down further to Natural Water Retention Measure (NWRM), and "Retention" being the core function targeted, biophysics would mean in the first instance the factors related to the water balance. This first set of impacts is called **Direct biophysical impacts: Mechanisms of Water Retention**. In the second instance it means all other factors that are enabled or improved by this retention and that can be monitored in or near the aquatic environment, i.e. **Indirect Biophysical Impacts resulting from Water Retention** (which, as noted above, may include impacts to air and terrestrial habitats as well as the aquatic environment).

All these biophysical impacts contribute in turn to provide ecosystem services (see for more details chapter III) meeting policy objectives (see for more details chapter V) established by the EU water legislation, and the other environmental policy objectives beyond water, of which in the legislation like the Habitat and the Bird Directive (HD, BD), and the EU strategies like Green Infrastructure strategy, or strategy on adaptation to climate change.

Within water legislation for instance, the first Water Framework Directive (WFD) was published by the European Commission in 2000 and updated later in 2006 to address a concern touching European citizens: *"When asked to list the five main environmental issues that Europeans are worried about, averaged results for the EU25 show that nearly half of the respondents are worried about "water pollution" (47%), with figures for individual countries going up as far as 71%. This demand by citizens is one of the main reasons why the Commission has made water protection one of the priorities of its work. The new European Water Policy will get polluted waters clean again, and ensure clean waters are kept clean."*

The example of the WFD has since been reproduced and led to other European Directives and strategies such as the Floods Directive (FD), the Marine Strategy Framework Directive (MSFD) and the 2020 Biodiversity Strategy.

Today's policy consists in working towards a good environmental status and privileging a functioning based on river basins. NWRM, thanks to their multi-functionality, are the most adapted to this change: they are linked to key environmental legislation and strongly encouraged by the European Commission. They offer the best possible combination to answer EU policy objectives and address the concerns of Europeans.

This document proposes a framework to organise the key NWRM biophysical mechanisms and impacts and link them to their associated Ecosystem Services and to Policy Objectives.

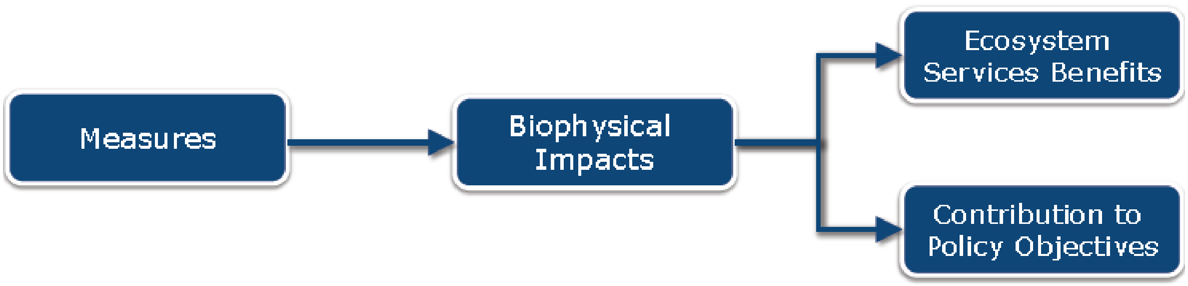
## II. What are the NWRM biophysical impacts?

It is important to go beyond the multi-functionality aspect included in NWRM definition, to understand how NWRM work. It is central to building the evidence base on NWRM, structuring the knowledge, and analysing the objectives and benefits of implementing NWRMs. Biophysical impacts are the central evidence component which enable benefits and policy objectives to be realised. We therefore must think about biophysical impacts in a structured manner:

- The mechanisms by which measures retain water
- The biophysical impacts that result from water retention
- Their contribution to meeting policy objectives

And separate these from consideration of the outcomes of these impacts addressed in separate document:"Delivering ecosystem services benefits (see SD n°4 Benefits of Natural Water Retention Measures - What are the benefits of NWRMs?)"

This can be represented as follows:



## SD2: Biophysical impacts of NWRM and contribution to the EU policy objectives

A structured grouping of biophysical impacts of NWRM can be proposed using the above mentioned two groups (mechanisms of water retention, and resulting biophysical impacts) and separated in a set of 17 types of impacts. They are represented as in the following figures and further detailed in the associated table.

**TABLE 1: STRUCTURED CLASSIFICATION OF POSSIBLE BIOPHYSICAL IMPACTS OF NWRM**

| | | | | |
|---|---|---|---|---|
| **Direct biophysical impacts: Mechanisms of Water Retention** | Slowing and Storing Runoff | 1 | **Store runoff** | Features that capture surface runoff and store it, e.g. a detention pond. The water is released at a slower rate than the original runoff, either back to surface water or infiltrating to groundwater. |
| | | 2 | **Slow runoff** | Features that slow the movement of surface water but without storage, for example by increasing surface roughness, e.g. a swale. |
| | | 3 | **Store river water** | Features that capture river water at times of high flow and provide storage, i.e. connectivity to floodplain (either open or controlled connection) |
| | | 4 | **Slow river water** | Features that reduce the rate of flow in a river or stream, for example by increasing the bed roughness or increasing the channel length by introducing meanders |
| | Reducing Runoff | 5 | **Increase evapotranspiration** | Capture of rainfall by vegetation (i.e. planting on nude soil or planting vegetation with a higher rate of evapotranspiration), increasing storage within the canopy and increasing evapotranspiration, thereby reducing total runoff. E.g. afforestation |
| | | 6 | **Increase infiltration and/or groundwater recharge** | Features that encourage the infiltration of rainfall and runoff to groundwater. This may be in the form of specific features such as an infiltration basin, or through increased permeability |
| | | 7 | **Increase soil water retention** | Improved storage of rainfall by increasing the capacity of soil to retain water, for example by increasing the organic matter content |
| **Indirect Biophysical Impacts : Resulting from Water Retention** | Reducing Pollution | 8 | **Reduce Pollutant Sources** | Features that result in a reduction in the sources of pollutants, for example changes to agricultural practices that may also have an effect to reduce the application of pollutants |
| | | 9 | **Intercept Pollution Pathways** | Features that intercept pathways for diffuse pollution to enter water bodies, for example creation of wetlands that remove particulate pollution from urban runoff |
| | Soil Conservation | 10 | **Reduce Erosion and/or Sediment Delivery** | Reduced erosion or the overland conveyance of sediment through, for example, preventing surface runoff or slowing the rate of runoff |
| | | 11 | **Improve Soils** | Improvement in the quality of soils for example through increase in organic matter content and nutrient retention |
| | Creating Habitat | 12 | **Create Aquatic Habitat** | Features that result in the creation of aquatic habitats, for example retention ponds that create permanent aquatic habitat |
| | | 13 | **Create Riparian Habitat** | Features that result in the creation of riparian habitats, for example the restoration of floodplains |
| | | 14 | **Create Terrestrial Habitat** | Features that create terrestrial habitats, for example agricultural buffer strips around field borders |
| | Climate Alteration | 15 | **Enhance Precipitation** | Reinforcing the water cycle to increase precipitation and improve vegetation status, for example targeted planting for intercepting precipitation |
| | | 16 | **Reduce Peak Temperatures** | Resulting from increasing evapotranspiration via planting trees and other types of vegetation in dry and hot areas |

| | | | | |
|---|---|---|---|---|
| | | 17 | **Absorb and/or Retain $CO_2$** | For example, changes to vegetation encouraging the uptake of $CO_2$ or protection of carbon stores such as peatland |

The first part of the table, named "Direct biophysical impacts: Mechanism of Water Retention", focuses on the primary function of NWRMs, as all measures aim at retaining water in a wide variety of ways. If there is **no water retention** (be it in wetlands, plants, surface water or in the subsurface), then the measure cannot, by definition, be referred to as an **NWRM**. The second part of the table, named "Biophysical Impacts resulting from Water Retention", focuses on impacts that occur in addition to or as a result of the water retention. Those two main categories are then split into several parts – given in second column – classifying all impacts according to their overall effect on the environment. At its lowest level, the frame gives a total of 17 biophysical impacts with their definition.

This separation in to primary and secondary functions is not to belittle the resulting indirect biophysical impacts, which in fact may often represent the main aims of NWRM. The classification has been split this way to recognise the necessity for water retention as a matter of definition, but that the purpose of that water retention may be to cause other impacts such as a change to water quality. This is reflective of the definition for NWRM, which states that they are "multi-functional measures". The criteria presented here aim to accompany the classification of measures already existing and to create a better understanding of the effects NWRM can have on a changing environment.

Having structured the biophysical impacts, it is then possible to analyse the NWRMs along these lists.

### II.1. Direct biophysical impacts: Mechanisms of Water Retention (BP1 to BP7)

As detailed above, water retention is the primary 'function' of any NWRM, in that it must exist in order to provide the range of other impacts and resulting benefits. Overall the land occupation has a major influence on the rainfall run-off transfer curve and implementing NWRM can have a positive effect on water retention. To ease the analysis, retention impacts are split in two categories:

- those having an influence on distribution of the (rain) water falling on the area over time (slowing and storing runoff). This approach to water retention involves temporarily storing runoff and/or river water, releasing it at a more controlled rate over a longer period of time.

- those having an influence on the volume available (reducing runoff). This approach to water retention involves the more 'permanent' retention of rainfall at source, primarily relating to changes to land use management that increase evapotranspiration and increase the retention of water in soil and/or groundwater.

It is well recognised that NWRMs have different retention capacities, depending on their own characteristics. Retention may be provided through various means, including in surface water bodies themselves, in groundwater, and in terrestrial ecosystems. For example, the JRC proposes an approach connected to modelling needs that distinguishes aquatic ecosystems providing water, and terrestrial ecosystems storing it.

*"Water regulation refers to the influence ecosystems have on the timing and magnitude of water runoff, flooding and aquifer recharge, particularly in terms of water storage potential of the ecosystem. This service is closely related to water provision. For now, we made the distinction based on surface and subsurface water flows classifying ecosystems that*

*capture the surface flow (rivers, lakes, wetlands) as providers of water and terrestrial systems that store or hold as regulators of water."* (A European assessment of the provision of ecosystem services; JRC; 2011; Source No45; p24)

It is clear therefore that the functions of water retention can have an influence during both wet and dry periods, by more effectively retaining precipitation that falls on a catchment, and thereby potentially increasing the water still available in a catchment during drier periods. Clearly the extent to which this will occur for an individual measure depends on its retention time (for example, some storm runoff features are designed to only store water for a few hours, in order to have capacity available for subsequent events), but in general, this wider definition of 'water retention' is an important aspect of NWRM.

This is relevant with respect to the Water Framework Directive, within which achievement of Good Ecological Status (GES) entails a water quantity component. By improving water retention in the catchment, particularly where groundwater recharge is improved, NWRM may play a role in the maintenance of environmental flows and hence achievement of GES as stated in the following (see also work of the WFD CIS Working Group).

***"According to the Directive, to achieve "good ecological status" there must be a balance between water abstraction and recharge of the groundwater bodies that would thus guarantee minimum environmental flows for water bodies."*** *(LIFE's Blueprint for Water Resources; © European Union; 2012; (Source No34); p9)*

### II.1.1. Slowing and storing run-off (BP1 to BP4)

The method by which runoff and river water can be slowed down or 'stored' varies greatly across the range of measures that we consider to be NWRM. For example, some Sustainable Drainage Systems (SuDS) are specifically designed for detention, with a design storage capacity to capture local runoff and store it temporarily, allowing release downstream at a more controlled rate. In doing so, detention basins contribute to reducing the impact on downstream runoff of impermeable surfaces in urban areas or compacted soils in agricultural areas. On a larger scale, the floodplain of a river exists to 'store' excess river flow and, in doing so, provides a slowing function that may reduce or alter the flood peak downstream, and help retain water to support river flows in dry periods. Similarly, increasing the land occupation by vegetation, in urban or rural areas, provide slowing, storing and in some cases reduction functions. However many other measures also slow and/or store runoff or river flow in less obvious ways, for example some types of river-restoration can increase the capacity of the river channel, while woody debris in forested areas may provide localised blockages and associated storage on small streams.

Nevertheless, while in theory the function of water retention is provided by these measures, in practice we may still need to be reassured that this will be the case, and that it will continue to be effective over time. While provision of evidence is relevant to all types of impacts (i.e. we must have evidence rather than simply assume the 'multiple benefits' for which NWRM are promoted), it may be of particular importance to be able to design measures able to address flooding events of the magnitude water stakeholders want to tackle, due to the potential consequences of incorrect assumptions.

Evidence of intensity of effectiveness is provided in the factsheets relating to individual measures, referring to available research, literature and studies and show considerable variability. For example, CREW (2012) reviewed the effectiveness of SuDS measures for flood management in urban areas, particularly in relation to performance under saturated conditions and long term efficiency as a device becomes established. The report examined the performance of a range of devices (green roofs, rainwater harvesting, pervious paving, infiltration devices and swales), reviewing the available evidence relating to the impacts that they have on managing flood scenarios. A key finding of the review was the uncertainty associated with the performance of SuDS devices. In some cases this apparent uncertainty is due to contrasting research methodologies and metrics, which may appear to give quite differing results. However, equally significant is the design, maintenance and catchment characteristics associated with the devices considered, which can significantly influence the short-term and long-term effectiveness of these types of measures. Antecedent conditions are also important, with measures being less effective under already saturated conditions: with this in mind, designing an appropriate retention time is important.

Clearly, SuDS should and do provide a function of water retention, but the evidence shows that they must be appropriately designed and maintained in order to ensure that function continues. More widely, their selection and design at a catchment scale is also of importance. As explained in the following, implementing NWRM is a complex exercise where it is necessary to carefully study the local situation and hydraulic behaviour to correctly select and design the measures so that they can have a measurable impact together with avoiding negative effects like longer flood period. CREW (2012) discussed this from the perspective of Natural Flood Management: "Identifying the impact of specific [Natural Flood Management] NFM measures (independent of other factors) is difficult, but there is evidence to suggest that they can reduce flood risk at the local scale… There is currently no conclusive evidence that NFM features can be used to reduce flood risk at the catchment scale, and Mayor et al. (2011) note that "...extrapolation of runoff values between scales or between catchments of different sizes is meaningless…There is currently no conclusive evidence that NFM features can be used to desynchronise flood peaks, and there is concern that simplistic application could result in unforeseen outcomes, e.g. Nisbet & Thomas (2008) caution that "…a possible downside of de-synchronisation, however, is that by extending the flood hydrograph there is a risk of consecutive flood events contributing to higher flood peaks if they coincided with the delayed recession limb of the flood hydrograph"... Whilst the current lack of evidence and uncertainties does not imply that NFM measures cannot make a significant contribution towards flood risk reduction, it does highlight the need for continuing research in this area. There are now a number of ongoing and planned UK catchment scale 'demonstration projects' that have the potential fill this current knowledge gap." (Natural flood management (NFM) knowledge system: Part 2 - The effect of NFM features on the desynchronising of flood peaks at a catchment scale; CREW; 2012). Once again, this is not to suggest that NFM is ineffective, but highlights the need to carefully consider implementation and potential influences at differing scales.

### II.1.2. Reducing run off (BP5 to BP7)

Rather than the surface water retention 'features' relevant to BP1-BP4, this second group of impacts uses the capacity of terrestrial ecosystems to capture (rain) water and of the receiving area to transfer part of the runoff to the soil or groundwater before it reaches surface waters. This can then in turn reduce the net run off reaching the surface water and the associated negative impacts, as well as encouraging groundwater infiltration and potentially contributing to improved base flows.

### II.1.2.a. BP5 Increase evapotranspiration

An increase in evapotranspiration may occur as a result of a change in land use (e.g. to forestry) or change in crop type or cropping practices. Details are provided in the individual factsheets.

It is not always easy to distinguish evapotranspiration from increase of roughness, increase of water retention in organic matter (especially in forest area) or of infiltration capacity, but in practice that may be of minor concern, as long as the overall impact of the vegetation can be clearly demonstrated. For instance it was shown **Woodland creation** reduces by 30-45% the surface runoff compared to agriculture land.

### II.1.2.b. BP6 Increase Infiltration and/or groundwater recharge

Infiltration occurs naturally in all landscapes, although to varying extents depending on environmental factors such as geology, vegetation type and rainfall intensity. Infiltration replenishes groundwater supplies and supports baseflow to rivers. Modification in many catchments has, over time, reduced their natural infiltration capacity, both by complete prevention of infiltration (i.e. impermeable surfaces associated with buildings, roads, car parks etc), and gradual degradation through other changes in land-use and soil compaction (e.g. from agricultural activities).

It is more and more recognised that past management of soils and landscape have led to increased negative unwanted impacts related to water. For instance in the agriculture sector, the implementation of drainage systems to dry lands and transfer water rapidly to the aquatic ecosystem, or the filling of small ponds to gain land have generated impacts on the water curve in the aquatic ecosystem. Similarly in urban areas, the increase in soil sealing by densification of habitats and roads have led to the need to rapidly drain rainwater downstream and this is more and more recognised: *"The tendency of building projects to 'seal' soil has a negative impact on natural water systems - it reduces the availability of soil to capture and process water. Such soil sealing can lead to a dramatic increase – both in volume and velocity - in surface water run-off, increasing flood risks, particularly in settlements that are built without adequately considering environmental issues."* *(LIFE's Blueprint for Water Resources; © European Union; 2012; Source No34; p48).* Approaches to avoiding and mitigating soil sealing (focussed on urbanisation) were considered by the European Commission in 2011 (Prokop *et al.*, 2011).

Increasing infiltration through use of NWRM may encompass:

- Restoring permeable surfaces, either by restoring more natural land uses, using less compacting agricultural and forestry practices, or by artificial means such as permeable paving;
- Restoring or changing vegetation cover of soil. For example, studies in wet woodlands have shown that infiltration rates were up to 60 times higher within **native woodland shelterbelts** compared to grazed pasture. *(Study of Pressures and Measures in RBMPs, 2013)*
- Creating areas with enhanced surface permeability, to encourage local infiltration and compensate for surrounding impermeable areas, for example infiltration basins. CREW (2012) found in a review of SuDS performance that *"All the reviewed studies […] show that infiltration devices have an effect on stormwater, reducing surface runoff volume as well as lowering and delaying stormwater runoff peaks."* *(Natural flood management (NFM) knowledge system: Part 1 – Sustainable urban Drainage Systems (SuDS) and flood management in urban areas; CREW; 2012)*
- Providing recharge directly to groundwater by artificial means (see measure N13).

#### II.1.2.c. BP7 Increase soil water retention

Of course dryness, slope, imperviousness or granulometry (from sand to clay) are important parameters acting on the infiltration capacity, which is itself linked to soil storage capacity. However, some key properties of the soil: coverage by vegetation, organic matter content and structure of the soil also dependent on the living organisms it contains are crucial to determine the soil capacity and from that define possible improvements.

Changes to land management practices can improve soil structure in a manner that increases its water retention capacity. This can be done by :

- increase in organic matter content which leads to improved soil structure,
- increased soil permeability as a result of increased root penetration,
- increased surface roughness (soil type and vegetation) which slow the flow of water and allow increased time for infiltration, for example by changing agricultural practices, or as water levels recede on a floodplain.

This makes this type of impact more relevant to measures applied in Agriculture or forestry sectors as organic matter and soil permeability are linked to the vegetation. However such measures are also relevant for the urban sector and 'natural areas' where vegetation is a key component.

## II.2. Indirect Biophysical Impacts: Resulting from Water Retention (BP8 to BP17)

This group of impacts describes the effects that may result from the function of water retention. In fact, particularly when considered from the perspective of the Water Framework Directive, these may be the main objective of the measures. In this respect, water retention is the 'means not the end', as the process of water retention enables a range of other biophysical impacts to be achieved.

### II.2.1. Reducing pollution (BP8 and BP9)

Many polluting substances are transported with water, either in the dissolved phase or with the particulate matter transported by flowing water. Retaining water in the catchment thus very often has a positive impact on pollution. Without considering the specific case of sediment (which is addressed in BP10 and BP11), this part considers the two main, direct, biophysical impacts that NWRM can have on water quality. While the respective characteristics of the soil and the polluting substances have to be considered to ensure adequate (positive) biophysical impacts on pollution, the available literature mainly focuses on three main groups of pollutants, which are nutrients, heavy metals and organic micro-pollutants. These groups comprise both substances found in dissolved phase and substances fixed to particulate matter. For the dissolved phase, physico-chemical parameters and the aquatic life can have a great influence on their availability and transfer, while for the fixed phase, the availability and transfer are closely related to that of sediment.

#### II.2.1.a. BP8 Reducing pollutants at source

NWRM can have an important biophysical impact on the reduction of pollution by preventing pollutants becoming entrained in runoff in the first place. This is in particular the case for nutrient parameters by different processes:

- Improved sediment retention by winter cropping to prevent bare soil and hence reduce rapid, sediment-laden runoff, with associated loss of nutrients to the aquatic environment.

Complete changes in land-use from arable can also provide similar benefit by replacement with permanent vegetation cover (see BP10-11 for further discussion).

- Changes in agriculture practices (or to other land uses) that require less fertiliser use or reduce leaching. For example:
  - "The **reduction of tillage** was found to decrease leaching by 0-25% compared with ploughing. […]" (RB Network on WFD and Agriculture, 2013),
  - In **converting arable land to grassland**, N loads are found to decrease by 22% and N concentrations by 21%. If extensive grazing takes place on the converted land, losses can reach 20kg N/ha/year, and additionally ammonium and nitrite losses to water could be reduce and direct and indirect N2O and NH3 emissions would decrease by around 90%. With regards to P, converting arable land without grazing corresponded to a 50% reduction in the loss of P, and adding extensive grazing resulted in a reduction of 42%. (Study of Pressures and Measures in RBMPs, 2013)
  - A study on effectiveness of phosphorus load reduction measures found that the **conversion of arable land to forests** reduces total phosphorus loading by 90%. (Study of Pressures and Measures in RBMPs, 2013)
  - For **changed crop rotations**, one project results suggest a potential pesticide reduction ranging from 6-25%. (Study of Pressures and Measures in RBMPs, 2013)
- Increased uptake by vegetation as in the following examples:
  - A study from Romania show that 10m wide **buffer zone** effectively reduced […] dissolve phosphorus by 30% and total nitrogen by 50%. (Study of Pressures and Measures in RBMPs, 2013)
  - Nitrate leaching can be reduced by **catch crops** on all soil types but has the biggest effect on sandy and shallow soils. An average reduction in N-leaching of 48% and a range of 0 to 98% has been identified. (Study of Pressures and Measures in RBMPs, 2013)

### II.2.1.b. BP9 Intercept pollution

In contrast to BP8, which limits pollution at source, BP9 'intercepts pollution' captures pollution once it has already been entrained in runoff. Most measures for which this is relevant achieve this biophysical impact by trapping sediment and preventing it from reaching surface waters (for example sediment settlement ponds or filter strips).

In addition, in ponds and wetlands, vegetation may provide a bioremediation capacity and take up a range of pollutants (e.g. nutrients and heavy metals), removing them from water.

By retaining water, NWRM can favour sedimentation but also specific physical-chemical conditions able to fix or destroy the substances like retrogradation of phosphorus, well known phenomena in agriculture science, fixation of heavy metals or de-nitrification in wetland areas, or other processes for organic micropolluants as detailed in the following sources:

*In Finland, experts estimate that on a catchment scale,* ***wetlands*** *can trap from 5 to 30% of nutrients and on some actively monitored wetlands, nutrient retention can be up to 50%. Studies in Finland and Swedish report that, through the retention runoff, wetlands reduced 25-48% of phosphorus and 20-90% of nitrogen overall. (Study of Pressures and Measures in RBMPs, 2013)*

*"Studies have shown that physical, chemical and biochemical processes associated with water movement within the subsoil – so-called 'Soil Aquifer Treatment' (SAT) - represent an alternative and natural way of reducing the presence*

*of "emerging organic micropollutants" in water and soils."* (LIFE's Blueprint for Water Resources; © European Union; 2012; (Source No34); p11)

By acting on the management of vegetation, NWRM can also improve the ecosystem health, thus increasing the consumption of nutrients or reducing the need to treat pests.

*The capacity of freshwater ecosystems to remove nitrogen can be expressed using the in-stream retention efficiency (%), which explains what portion of the nitrogen entering rivers is retained. Fractional nutrient removal is determined by the strength of biological processes relative to hydrological conditions (residence time, discharge, width, volume).* (A European assessment of the provision of ecosystem services; JRC; 2011; Source No45; p27)

In addition to uptake by vegetation, some measures are specifically designed to provide capture of sediments, and hence of associated pollutants. In particular, many SuDS measures, in both urban and rural (agricultural or forestry) settings, perform this function.

## II.2.2. Soil conservation (BP10 and BP11)

### II.2.2.a. BP10 Reduce Erosion and/or Sediment Delivery

NWRM have the potential to reduce erosion, sediment loss and unwanted unnatural sediment deposition by a range of means including:

- Changes to land use or to agricultural practices to reduce bare soil. Permanent vegetation cover provides increased soil stability and can help to reduce the amount of sediment entrained in runoff;
- Measures to capture, store and slow runoff allow opportunities for sediment to be deposited from runoff before it reaches surface waters;
- Restoration of natural hydro-morphological processes can prevent unnatural patterns of erosion and deposition, for example by restoring the 'natural' river length and channel characteristics.

"*Land use, relief, soil properties and climate (wind and precipitation) are the predominant variables determining the magnitude of erosion. Vegetation, in particular forests, help conserving soils and prevent the siltation of waterways and landslides.*

*Accelerated soil erosion by water as a result of changed patterns in land use is a widespread problem in Europe. By removing the most fertile topsoil, erosion reduces soil productivity and, where soils are shallow, may lead to an irreversible loss of natural farmland. The capacity of natural ecosystems to control soil erosion is based on the ability of vegetation (i.e. the root systems) to bind soil particles thus preventing the fertile topsoil from being blown or washed away by water or wind."* (A European assessment of the provision of ecosystem services; JRC; 2011; Source No45; p36)

"*[…]. Clearly, pastures contribute to prevention of erosion and adoption of good management and practices has demonstrated significant reductions in erosion rates. Better information on European grasslands (both natural and agricultural) would be an asset for ecosystem services mapping and valuation.*" (A European assessment of the provision of ecosystem services; JRC; 2011; Source No45; p38)

It is well recognised that:

- soil management practices like reduced tillage: "*The **reduction of tillage** was found to decrease leaching by 0-25% compared with ploughing. Additionally was showed that reduced tillage systems can reduce P and sediment losses by 30-60% on clay soils and by up to 90% on loamy sand.*" (RB Network on WFD and Agriculture, 2013),

- plant management practices like winter cover crop: *According to a Finnish study,* ***plant cover*** *in winter can reduce erosion 10-40%.* *(Study of Pressures and Measures in RBMPs, 2013)*, or maintenance of certain plant communities: *"The following land cover classes are assumed to contribute to erosion prevention: Broad-leaved forest, Coniferous forest, Mixed forest, Natural grasslands, Moors and heathland, Sclerophyllous vegetation, Transitional woodland-shrub, Beaches, dunes, sands." (A European assessment of the provision of ecosystem services; JRC; 2011; Source No45; p36)*

- or choice of the crop planted: ***Row crops*** *such as corn or beans reduce the high erosion potential of fallow land by half, although erosion remains excessive.* *(Study of Pressures and Measures in RBMPs, 2013)* can reduce erosion.

In this respect, some NWRM are particularly relevant for addressing erosion problems:

*A study from Romania show that 10m wide* ***buffer zone*** *effectively reduced leaching of suspended solids by 50-60% […].* *(Study of Pressures and Measures in RBMPs, 2013)*

*Regarding* ***Buffer Strip****, it has a retardation of sediment of 86-90% for the larger buffer strips but narrower buffers still reduce sediment loss by 70%. The effectiveness of well-maintained grass riparian buffers for sediment removal may be as high as 90 to 95%.* *(Study of Pressures and Measures in RBMPs, 2013)*

## III. Synthesis of the effectiveness of NWRM

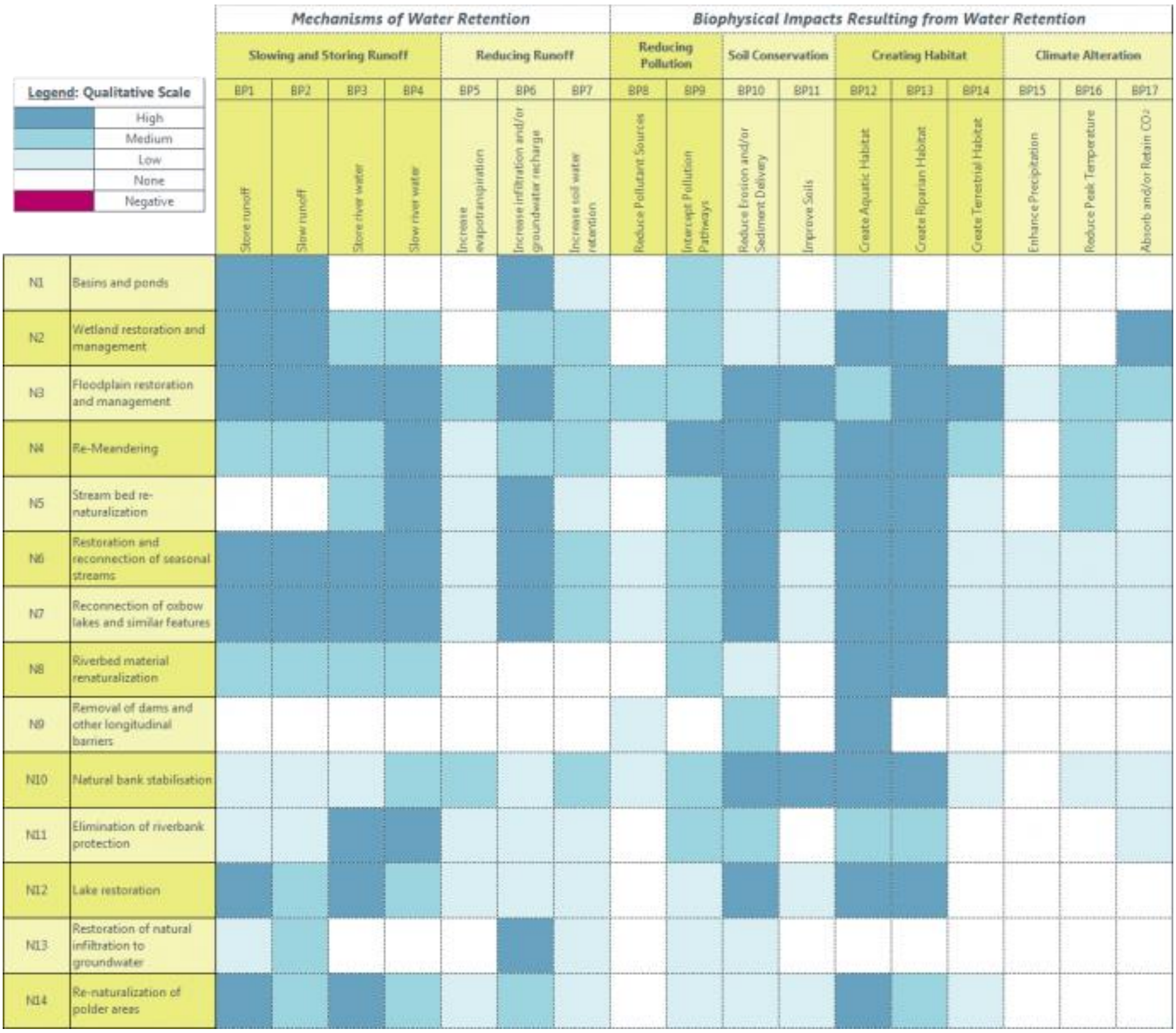
The 17 types of biophysical impacts have been submitted to experts of each scientific field in order to establish a generic qualitative scale measuring impact intensity by individual NWRM.

To ease the analysis a detailed knowledge base template was developed. To keep it manageable and understandable, qualitative rating for each biophysical impact, each ecosystem service and each policy objective was defined with 4 categories: no effect of the measure, low effect, medium effect or high effect. The choice between these categories is based on expert judgement supported by the information found with the literature review but also collected for the case studies and the support of the project and external experts involved for example in the Workshops. The purpose of this qualitative category is to provide a useful comparative assessment between the different biophysical impacts, ecosystem services and policy objectives respectively. During the elaboration and quality review of each NWRM factsheet, these ratings were thoroughly reviewed and revised where necessary. At the end of the project, they provide a robust tool to help managers to choose among the possible NWRM. The addition of new case studies, new pieces of literature and more generally new knowledge, should help refine this and progressively add quantitative rating, the quantitative values being currently mainly found in individual factsheets, case studies and Workshop presentations.

So effectiveness is seen as the positive intensity of an impact. A key advantage of this is to be able to select the most appropriate measure(s) for one or more targeted impacts.

**TABLE 2: OVERVIEW OF THE MATRIX BIOPHYSICAL IMPACTS X MEASURES FOR THE HYDROMORPHOLOGY SECTOR**

## SD2: Biophysical impacts of NWRM and contribution to the EU policy objectives




This method allows a clear comprehension of the matter via its direct visualisation in a comparative matrix.

**All matrices linking biophysical impacts with individual NWRM are available here on the website:** http://www.nwrm.eu/benefit-tables

As can be seen from the matrices on the given web page, the biophysical impacts vary greatly between the measures, although with some patterns for the measures of a same main sector. This clearly illustrates that different measures will be appropriate to different situations, depending on the desired outcome. Further detail of the main biophysical impacts of individual measures is also available in the individual measure factsheets.

Another way to link NWRM to their effectiveness is to link them to the main Ecosystem Services it can bring (closely linked to its biophysical impacts) and that are different depending on the NWRM. One viable way to assess NWRM effectiveness is therefore by taking all 14 Ecosystem Services it can have and linking them to the measures in a matrix, like for the biophysical impacts and with the same qualitative range. For more details see synthesis document n°4 and the website.

## IV. How do biophysical circumstances (basin characteristics) influence the impact of different measures?

The (broad) definition of NWRM covers a wide range of quite different techniques and infrastructures. The catalogue of measures proposed by the NWRM project and the key biophysical impacts identified above help structure and better define the NWRM. However, for each single NWRM, different techniques can be used and the implementer will have to customise it to local conditions so as to maximise the targeted biophysical impacts as recognised by various authors: *"The watershed and river network conditions must be more strongly considered, and river restoration should be done in a watershed context."* *(Bernhardt and Palmer, 2011; Hermoso et al., 2012; Lorenz and Feld, 2013)*

There are a wide set of specific local biophysical circumstances which can influence the impact of measures, and the weather condition is obviously an important one. For instance temperature and rainfall quantity and distribution over time have a great influence on the plant growth and evapotranspiration rates, but also on the availability of water in surface water streams or for implementing NWRM. The geochemical background can also influence the pollution reduction rates by disturbing the natural purification processes.

The regional networks identified also some key elements from past and current development in the local implementation of NWRM and that make each region specific. The Nordic part of Europe is more sensitive to urban long lasting flooding whereas the Danube part is more sensitive to big flooding having an impact on all sectors, and southern part of Europe is more subject to drought events and flash floods. The western part, more urbanised, requires consideration not only of water management but also spatial planning. It is also possible to distinguish different pattern of impacts related to the energy flows have: low energy flows have generally a higher resilience with a slow change of flow and low sediment transport, whereas high energy flows can have a very rapid change of flow associated with a high sediment transport.
It is also highly important to consider monitoring of these key expected biophysical impacts to show they are effectively altered by the implementation of the measures: *"Some restoration projects have been successful in enhancing biological quality elements (BQEs) (see reviews in Roni et al., 2005; Roni and Beechie, 2013), but many projects have also found no or minor ecological improvements from restoration measures. "(Pretty et al., 2003; Sear and Newson, 2004; Lepori et al., 2005; Schwartz and Herricks, 2007; Haaset et al., 2013; Lorenz and Feld, 2013).* Many more simply have no monitoring and hence no evidence of how effective they actually are. Monitoring, and other approaches to assessing effectiveness are discussed in Question 4.

## V. What are the EU policy objectives relevant for NWRM?

The European Commission released the first set of best environmental practices concerning the water sector in 2000 with the Water Framework Directive (WFD), in which the first definition for the Good Environmental Status (GES) is available. Since then, the Common Implementation Strategy allowed intensive discussion and clarification and the scope of WFD has been extended and supported by other Directives and strategies like the Floods Directive (FD), the Groundwater Directive, or the 2020 Biodiversity Strategy, and with this support came other notions linking the water sector to a high number of fields like the protection of ecosystems and the adaptation to climate change (for more details see in the section governance, implementation and financing the full Synthesis document n°10).

> Land use management is a vital tool for the regulation of both water quality and quantity. Water quality is adversely affected by relatively high surface runoff and erosion (Fiener et al 2011) and water quantity is manifested in both water scarcity and the flood events (Creed et al 2011). The implementation of appropriate Natural Water Retention Measures (NWRMs) have as main purpose a reduction in surface runoff following rainfall events in order to reduce flood risk.
>
> ***Forest Research, 2010***

The link to the key environmental EU legislation is crucial to convince the targeted end-users of the benefits of applying NWRM. In this respect, linking NWRM to the effectiveness criteria as defined by the Directives is key. Table 1 lists all the EU policy objectives chosen by the project experts to cover the wide range of NWRM benefits.

Note: all EU Directives and policy documents linked to NWRM are listed in synthesis document 10.

**TABLE 3: EU POLICY OBJECTIVES**

| | | | | |
|---|---|---|---|---|
| **Policy Objectives - *How NWRM contribute to meeting EU Policy Objectives*** | **Water Framework Directive** | **Achieve Good Surface Water Status** | **Improving Status of Biology Quality Elements** | Measure can contribute to improving the status of Biology quality elements for surface waters listed in WFD Annex V |
| | | | **Improving Status of Physico-Chemical Quality Elements** | Measure can contribute to improving the status of Physico-Chemical quality elements for surface waters listed in WFD Annex V |
| | | | **Improving Status of Hydromorphology Quality Elements** | Measure can contribute to improving the status of Hydromorphology quality elements for surface waters listed in WFD Annex V |
| | | | **Improving Chemical Status & Priority Substances** | Measure can contribute to reduction in priority hazardous substances in surface and groundwater |
| | | **Achieve Good Groundwater Status** | **Improved Quantitative Status** | Measure can contribute to achieving Good groundwater quantitative status |
| | | | **Improved Chemical Status** | Measure can contribute to achieving Good groundwater chemical status |
| | | **Prevent Deterioration** | **Prevent Surface Water Status Deterioration** | Measure can contribute to preventing the deterioration of surface water body status |
| | | | **Prevent Groundwater Status Deterioration** | Measures can contribute to preventing the deterioration of groundwater body status |
| | **Floods Directive** | | **Take Adequate and Co-ordinated measures to reduce flood risks** | Measure contributes to reducing flood risks as part of co-ordinated flood management plan |
| | **Habitats and Birds Directives** | | **Protection of Important Habitats** | Measure can contribute to protection of designated habitats under the Habitats and Birds Directives |
| | **2020 Biodivers ity Strategy** | | **Better protection for ecosystems and more use of Green Infrastructure** | Measure promotes the protection of ecosystems and the enhancement of natural ecosystem function, or enhances the use of Green |

| | | | |
|---|---|---|---|
| | | | Infrastructure |
| | | **More sustainable agriculture and forestry** | Measure promotes more sustainable agriculture and forestry practices |
| | | **Better management of fish stocks** | Measure can contribute to better management of fish stocks and fisheries |
| | | **Prevention of biodiversity loss** | Measure can enhance biodiversity or prevent biodiversity loss |

## VI. Construction of the matrix linking NWRM biophysical impacts to EU policy objectives

Based on the details of the biophysical impacts of NWRM defined previously and the key policy objectives, the following matrix was calculated by crossing two other matrices: the one linking NWRM to the policy objectives described above, and the one linking NWRM to their biophysical impacts. A blue square indicates a link between a policy objective (PO) and a biophysical impact (BP).

## SD2: Biophysical impacts of NWRM and contribution to the EU policy objectives

**MATRIX 1: NWRM BIOPHYSICAL IMPACTS LINKED TO EU POLICY OBJECTIVES**

| | | | | | NWRM BIOPHYSICAL IMPACTS | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Mechanisms of Water Retention | | | | | | | Biophysical Impacts Resulting from Water Retention | | | | | | | | | |
| | | | | | Slowing and Storing Runoff | | | | Reducing Runoff | | | Reducing Pollution | | Soil Conservation | | Creating Habitat | | | Climate Alteration | | |
| | | | | | Store runoff | Slow runoff | Store river water | Slow river water | Increase evapotranspiration | Increase infiltration and/or recharge | Increase soil water retention | Reduce Pollutant Sources | Intercept Pollution Pathways | Reduce Erosion and/ or Sediment Delivery | Improve Soils | Create Aquatic Habitat | Create Riparian Habitat | Create Terrestrial Habitat | Enhance Precipitation | Reduce Peak Temperature | Absorb and/or Retain CO2 |
| | | | | | BP1 | BP2 | BP3 | BP4 | BP5 | BP6 | BP7 | BP8 | BP9 | BP10 | BP11 | BP12 | BP13 | BP14 | BP15 | BP16 | BP17 |
| **EU POLICY OBJECTIVES** | Water Framework Directive | Achieve good surface water status | Improving Status of Biology Quality Elements | PO1 | | | | | | | | ■ | ■ | | | ■ | ■ | ■ | | | |
| | | | Improving Status of Physico-Chemical Quality Elements | PO2 | | | | | | | | ■ | ■ | | | | | | | | |
| | | | Improving Status of Hydromorphology Quality Elements | PO3 | | | | ■ | | | | | | ■ | ■ | | | | | | |
| | | | Improving Chemical Status & Priority Substances | PO4 | | | | | | | | ■ | ■ | | | | | | | | |
| | | Achieve good groundwater status | Improved Quantitative Status | PO5 | | | | | | ■ | | | | | | | | | | | |
| | | | Improved Chemical Status | PO6 | | | | | | | | ■ | ■ | | | | | | | | |

| | | | | NWRM BIOPHYSICAL IMPACTS | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Mechanisms of Water Retention | | | | | | | Biophysical Impacts Resulting from Water Retention | | | | | | | | | |
| | | | | Slowing and Storing Runoff | | | | Reducing Runoff | | | Reducing Pollution | | Soil Conservation | | Creating Habitat | | | Climate Alteration | | |
| | | | | Store runoff | Slow runoff | Store river water | Slow river water | Increase evapotranspiration | Increase infiltration and/or recharge | Increase soil water retention | Reduce Pollutant Sources | Intercept Pollution Pathways | Reduce Erosion and/ or Sediment Delivery | Improve Soils | Create Aquatic Habitat | Create Riparian Habitat | Create Terrestrial Habitat | Enhance Precipitation | Reduce Peak Temperature | Absorb and/or Retain CO2 |
| | | | | BP1 | BP2 | BP3 | BP4 | BP5 | BP6 | BP7 | BP8 | BP9 | BP10 | BP11 | BP12 | BP13 | BP14 | BP15 | BP16 | BP17 |
| EU POLICY OBJECTIVES | | Prevent Deterioration | Prevent Surface Water Status Deterioration | PO7 | | | | ■ | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| | | | Prevent Groundwater Status Deterioration | PO8 | | | | | | ■ | | ■ | ■ | | | | | | | | |
| | FD | | Take Adequate and Co-ordinated measures to reduce flood risks | PO9 | ■ | ■ | ■ | ■ | | ■ | ■ | | | ■ | | | | | | | |
| | HD & BD | | Protection of Important Habitats | PO10 | | | | ■ | | | | ■ | ■ | | | | | | | | |
| | 2020 Biodiversity Strategy | | Better protection for ecosystems and more use of Green Infrastructure | PO11 | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| | | | More sustainable agriculture and forestry | PO12 | | | | | | | | ■ | ■ | ■ | | | ■ | ■ | | | |

## SD2: Biophysical impacts of NWRM and contribution to the EU policy objectives

| | | | | NWRM BIOPHYSICAL IMPACTS | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Mechanisms of Water Retention | | | | | | | Biophysical Impacts Resulting from Water Retention | | | | | | | | | |
| | | | | Slowing and Storing Runoff | | | | Reducing Runoff | | | Reducing Pollution | | Soil Conservation | | Creating Habitat | | | Climate Alteration | | |
| | | | | Store runoff | Slow runoff | Store river water | Slow river water | Increase evapotranspiration | Increase infiltration and/or recharge | Increase soil water retention | Reduce Pollutant Sources | Intercept Pollution Pathways | Reduce Erosion and/ or Sediment Delivery | Improve Soils | Create Aquatic Habitat | Create Riparian Habitat | Create Terrestrial Habitat | Enhance Precipitation | Reduce Peak Temperature | Absorb and/or Retain CO2 |
| | | | | BP1 | BP2 | BP3 | BP4 | BP5 | BP6 | BP7 | BP8 | BP9 | BP10 | BP11 | BP12 | BP13 | BP14 | BP15 | BP16 | BP17 |
| | | Better management of fish stocks | PO13 | | | ■ | ■ | | | | ■ | ■ | | | ■ | | | | | |
| | | Prevention of biodiversity loss | PO14 | | | | | | | | ■ | ■ | ■ | | ■ | ■ | ■ | | | |

## VII. Assessment of the method and analysis of the matrix

At first glance, it appears that NWRM, through their biophysical impacts, address a wide range of objectives linked to the PO11 and thus the 2020 Biodiversity Strategy. This aspect is due to the definition of NWRM itself. As a reminder, NWRM "are multi-functional measures that aim to protect water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes." It is therefore logical that PO11, closely linked to the well-being of ecosystems, is met by the widest number of NWRM biophysical impacts.

> Working with Nature "offers real opportunities for flood risk management with many additional benefits and the measures support the aims of the WFD and Climate Change adaptation policy. There is ready linkage to land-use and, in particular, agriculture and forestry so measures can be implemented at a forest or farm level. They are expected to be cheap and resilient, they work well with a combination of other approaches to flood risk management and they produce multiple benefits and fit well with the source and pathway approach."
>
> ***First NWRM workshops, 2014***

However, other policy objectives like PO7 and PO9, which are not so directly linked to the definition of NWRM itself, are linked to approximately half of NWRM biophysical impacts. As a matter of fact, PO7 and PO9 are both directly linked to surface water. While PO7 concerns the deterioration of surface water quality, PO9 refers to surface water quantity and its management during floods. It shows that most of NWRM biophysical impacts address the policy goals concerning surface water. In comparison, PO8 is met by only three biophysical impacts. This is due to the fact that NWRM are mostly implemented above the ground.

From the biophysical impacts' point of view, BP8 and BP9 are the ones linked to the most policy objectives. As they both concern pollution, this link shows the importance given by the overall European environmental policy to the reduction and control of pollution. In fact, the deterioration of water quality due to industrial rejections has been known for decades and is now completely integrated to the European population's way of thinking. Matrix 1 thus perfectly illustrates how important information concerning environmental best practices can be for the evolution of human practices.

Now if the analysis is refined and focuses on each Directive, it becomes interesting to have a look at the matrix linking NWRM directly to their corresponding policy objectives here (see synthesis document 10). Each sector (Agriculture, Forest, Hydromorphology, and Urban) has its own influence depending on the policy, as does each biophysical impact.

The WFD has a pyramidal organisation separating its main policy objectives into two main subjects: surface water and groundwater. As seen above, NWRM biophysical impacts are mainly linked to surface water. However, the groundwater aspect cannot be separated from the surface water aspect at the risk of compromising the balance existing between them. The WFD, as the oldest water Directive, is indeed attached to respecting it.

The FD, as well as the HD and BD, is summed up by only one objective. Both PO9 and PO10 are met by several biophysical impacts, showing once again the multi-functionality of NWRM. As to the 2020 Biodiversity Strategy, all policy objectives displayed in its section are linked to several NWRM biophysical impacts.

> The introduction of NWRMs within a "step-wise and cyclical approach of the river basin management planning process makes it well suited to adaptively manage climate change impacts. This approach means that we can revisit plans to scale up or down our response to climate change in accordance to monitored data, and can avoid over-investment now. On the other hand, it is important that long term climate projections are built in to the design of measures (driven by current pressures) that have a long design life and high costs. As such, inclusion of climate change in assessment of pressures is important".
>
> ***EC, 2009***

The only biophysical impacts not linked to any policy objective are the ones concerning climate alteration. In fact, there are special policy documents explaining the EU strategy regarding climate change, like the Climate Change Adaptation Strategy or the Blueprint, but they do not give specific objectives to reach. Matrix 1 thus has its limits, and this is where it is interesting to look at the matrix linking each measure to its biophysical impacts. This matrix (available here on the website: http://www.nwrm.eu/catalogue-nwrm/benefit-tables) shows that the sectors that are most likely to address climate alteration are Forest and Hydromorphology.

## VIII. Conclusion

The NWRM project has gathered together information and evidence about a wide range of NWRM, structured to allow their use, and available on a website platform. The website provides a detailed matrix linking biophysical impacts and individual NWRM but also more insight into the different biophysical impacts of individual measures via the catalogue of NWRM, with for each measure a detailed factsheet discussing the impacts, benefits and costs found in relevant literature for the measure. In addition, individual case studies implementing these NWRM in different regions of Europe can be accessed, providing more details on examples of local circumstances and design of the measures.

As detailed above, a large part of NWRM biophysical impacts cover the policy objectives of the EU legislation. Three important points to sum up:

1. The link to the key environmental EU legislation is crucial to convince the targeted end-users of the benefits of applying NWRM. In this respect the effectiveness along the legislation effectiveness criteria (good status for WFD, mitigation of risks for FD, maintain or restore natural habitats for the Habitat Directive…) is key.
2. A single NWRM cannot overcome all expectations, i.e. reduction of nutrient inputs or of high waters using NWRM cannot be reached efficiently with one NWRM. Therefore the combination of a set of NWRM is a key factor for good effectiveness.
3. NWRM are by nature measures with multiple benefits, and hence implemented with a set of objectives. It is therefore important to consider some objectives may be covered to a lesser extent than an alternative option. This in turn can entail the need to consider specific trade-offs and the lower acceptable limits to still qualify the measure (ex: lowest accepted performance on the effectiveness criteria…).

Another important aspect of NWRM not covered by this synthesis but directly linked to the biophysical impacts of NWRM and the policy objectives they are meeting is the contribution of NWRM to Ecosystem Services (See the matrix developed mentioned in chapter III and detailed in Synthesis document n°4 and on the website). They are indeed the most important benefits from NWRM. They are benefits that humans derive from ecosystems, which support people around the world. These include, inter alia, provisioning of food and fibre, regulating and provisioning of water, soil productivity and use of natural areas for recreation or spiritual purposes.

Within the frame of this project, this document should be seen as a support document for decision makers, managers and practitioners. This document, detailing the different types of NWRM biophysical impacts as well as their generic effectiveness, and contribution to meeting policy objectives should help the dedicated stakeholders in choosing and implementing measures generating an optimum answer to their needs.

Users should not forget that this report is part of a global approach, and that the platform provides tools, methods and information that may evolve with the gathering of additional knowledge. So additionally, the individual NWRM factsheets should be carefully read without forgetting to take the environment local context into account.

# IX. List of references

Benis Egoh et al., *Indicator for mapping ecosystems*, 2012

Communication from the Commission the European Parliament, the Council and the Committee of the Regions *A Blueprint to Safeguard Europe's Water Resources*, 2012 – 34

CREW, 2012. Natural flood management (NFM) knowledge system: Part 1 – Sustainable urban Drainage Systems (SuDS) and flood management in urban areas;

CREW, 2012. Natural flood management (NFM) knowledge system: Part 2 - The effect of NFM features on the desynchronising of flood peaks at a catchment scale.

E. Anguiano, N.Rouyer, 2010. Mandate of the River Basin Network on WFD and Agriculture.

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

Forest Research website; http://www.forestry.gov.uk/fr/infd-5txhaj; consulted June 2015

JRC, University of Qaran, 2011. Training on environment concepts, http://www.e-environment.universityofqaran.com/The%20biophysical%20environment.html, consulted January 2015

JRC, 2011. A European assessment of the provision of ecosystem services – 45

NWRM project *"Concept Note: Natural Water Retention Measures (NWRM) and the WFD and other daughter Directives",* January 2014

Prokop, G., Jobstmann, H. And Schönbauer, 2011. Overview of best practices for limiting soil sealing or mitigating its effects in EU-27. Final Report.

S. Nixon et al., 2012. Comparative study of Pressures and Measures in the major RBMPs.

Stella consulting, Costs, benefits and climate proofing of natural water retention measures; 2010

http://ec.europa.eu/environment/water/water-framework/info/intro_en.htm; consulted June 2015