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# *Synthesis document n°3*

## *Assessment methods for effectiveness of Natural Water Retention*

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*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 (NWRMs) 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 NWRMs cover as described in *SD n°0: Introducing NWRMs. 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 NWRMs 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:** Floods Directive (FD), Water Framework Directive (WFD) - Please consult the NWRM glossary for more information.

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# I. Introduction

Firstly, we must be clear what we mean by effectiveness, and in particular, effectiveness for what? This depends on what we really want NWRM to achieve. As the previous questions have discussed, increased uptake of NWRM aims to improve and restore the natural hydrological functioning and related biophysical processes of catchments. Here there is a complex question to answer in terms of effectiveness. In particular, what do we want NWRM to be effective for? This may encompass a wide range of parameters including surface runoff, river flows, surface and groundwater water quality, biodiversity and more (i.e. the range of biophysical impacts discussed in Question 1). Indeed, as we have already seen, it is this multi-functionality of NWRM that is key to their value, and considering only a single aspect in isolation may underplay the overall benefits that they can provide. This overall benefits assessment is considered in Question 4. Here, we focus on approaches for understanding how effective NWRM are at achieving individual biophysical impacts including:

- Mechanisms of water retention: slowing and storing runoff and/or river flows;
- Resulting biophysical impacts: predominantly water quality. Other impacts including soil conservation, habitat creation and climate influences are also given some consideration, but span wide extents of natural sciences and cannot be covered here in full.

Many existing examples of NWRM, and indeed other environmental improvement projects, suffer from lack of quantitative evidence as to their effectiveness. Where post-implementation monitoring is carried out, it is often only for a short period which, in some cases, may be insufficient to allow a measure to become fully effective (for example, woodland development, which will take many years to mature). For example, Feld et al. (2011) note that *"Virtually all restoration project evaluations are restricted to a few years after restoration (e.g., 3-5 years), and significant uncertainties remain surrounding the long-term effects and sustainability of restoration measures."* Lack of evidence can make it harder to justify their value and their continued use in future. Therefore, approaches to establishing the effectiveness of a new measure (preferably by monitoring) should be incorporated as an integral part of implementation, not as an 'added extra'.

It is also extremely important not to limit assessments of effectiveness solely to a single parameter. Considering that one of the main attractions of NWRM is their potential ability to provide a range of benefits, monitoring of only a single parameter is likely to underplay its overall effectiveness and may make it appear less cost-effective in comparison to some other measures, when a full assessment across a range of impacts would show NWRM in a more favourable light.

To add to the complexity, it is not solely the effectiveness of an individual measure at its location that we are interested in. In many cases it will be the contribution of that measure to influencing catchment-scale processes, or even the potential for that measure to be incorporated in to a wider network of measures which overall (but not necessarily individually) influences catchment-scale processes.

It is beyond the scope of this assessment to consider the details of specific monitoring and modelling approaches/techniques, particularly considering how many different types of impact come in to play in relation to NWRM. The focus here is on determining the principles that should be applied in an assessment of effectiveness, which can be transferable across many different parameters and situations.

# II. Monitoring

## II.1. Site-scale

At the site-scale, i.e. local to a measure, assessments of effectiveness can be achieved by monitoring:

- Upstream and downstream of a measure. Clearly this depends on the type of measure. This type of approach is applicable to, for example, a detention basin (install monitoring at the inflow and outflow), or to a river reach that has had its connection to the floodplain restored (install monitoring on the river upstream and downstream). However it is not relevant to land-use changes where there is no 'upstream', in which case other approaches (as introduced below) will be more relevant. Where relevant, this type of monitoring provides an opportunity for clear and relatively unambiguous evidence of effectiveness to be collected;
- Both before and after a measure is implemented. This allows, over time, a comparison to be drawn as to how a site is responding to the measure. This type of monitoring should be relevant to any measure, and at a range of scales. It can encompass most types of impacts, for example hydrological, water quality, habitat and soil science. It must be initiated long enough prior to the measure being implemented to experience a range of climatic and hydrological conditions and, similarly, continued after installation for a sufficient length of time. It is not possible to specify an exact length of time that will be appropriate in all cases. In general the capture of at least a full hydrological year both before and after installation would be recommended, but some types of impacts, for example development of vegetation, increase in biodiversity or improved soil structure, may take much longer than this. In the latter examples, an annual monitoring regime may be more appropriate.
- At a control site as well as the 'impact' site. This requires selection of a site with similar baseline conditions, where the baseline state will be maintained, and could be monitored as such while the measure is implemented at the 'impact' site. Comparisons between impact and control sites can be challenging due to the number of variables to consider and potential differences in hydrological response between sites, but nevertheless can add considerable robustness to an impact assessment.

Ideally a combination of these approaches would be used. This allows a robust assessment and avoids assumptions about the causes of any changes in biophysical conditions. For example, a change in climatic conditions could be mistaken for the impact of the measure when monitoring before and after installation, but addition of a control site would allow that to be accounted for. In some environmental fields, this is known as the 'Before-After Control-Impact' (BACI) approach.

**Example 1: Upstream and Downstream Monitoring of Kylmäojan korpi wetland, Vantaa City, Finland**

A research project was carried out on an urban forested wetland to monitor the influence of the wetland on water quality and river flow. Continuous monitoring was carried out of water quality (dissolved oxygen, electrical conductivity, turbidity and temperature) and stream stage. Additional samples were also taken during events for more detailed water quality analysis. Samples were collected at the inflow and outflow of the wetland, allowing a clear assessment of the influence of the wetland. This showed that the wetland improved DO and slightly reduced EC and turbidity. The wetland provides a hydrological buffer, reducing the 'flashiness' of storm flows.

(Case study number 17. A.Taylor MSc thesis, University of Helsinki)

Capture of 'event' based data for river flow and water quality is often valuable, although changes to the baseflow regime over time will also be important and allow understanding of the full range of hydrological effects that NWRM may enable (from floods to droughts). In order to capture events, continuous monitoring is very useful (i.e. installation of automated monitoring equipment), since it helps to ensure that events are not missed, and provides a continuous picture of an event rather than just snap-shots (which may be harder to compare between events). However it is also possible through a carefully targeted manual regime. In non-event conditions, a manual regime, e.g. occasional or regular visits to manually measure flow or take water quality samples, may be sufficient to give an overview of the conditions. Changes to biology and soils, which are likely to develop over time in response to a changed hydrological, physical or chemical environment, may be best recorded with a standard sampling routine, repeated over a number of seasons and years.

## II.2. Catchment-scale

Catchment-scale monitoring allows the distribution and spatial extent of effects of a measure, or network of measures, to be established. This moves beyond the site-scale to consider how far the impacts of NWRM extend and how the effects of multiple measures may interact with each other. This is important for understanding how effective measures are not only at their location, but in having an influence at the catchment-scale.

Catchment-scale monitoring could be implemented at the catchment outlet or by introducing a monitoring network spread throughout the catchment. The latter, although more costly, is likely to provide more valuable and definitive information, particularly in a larger catchment. It will allow a picture to be built up throughout the catchment of the influence of individual and multiple measures, and the interactions between measures. In contrast, if monitoring is carried out only at the catchment outlet, it may be difficult to distinguish the influence of the measure or measures from other variables in the catchment. The distribution of monitoring across the catchment will depend on the distribution of measures, but should ideally include monitoring in proximity to individual measures, and at intervals from there to the catchment outlet, including at the confluence of any major tributaries.

The same principles as discussed above for the site-scale also apply at the catchment-scale, including monitoring before and after, and considering using a control site.

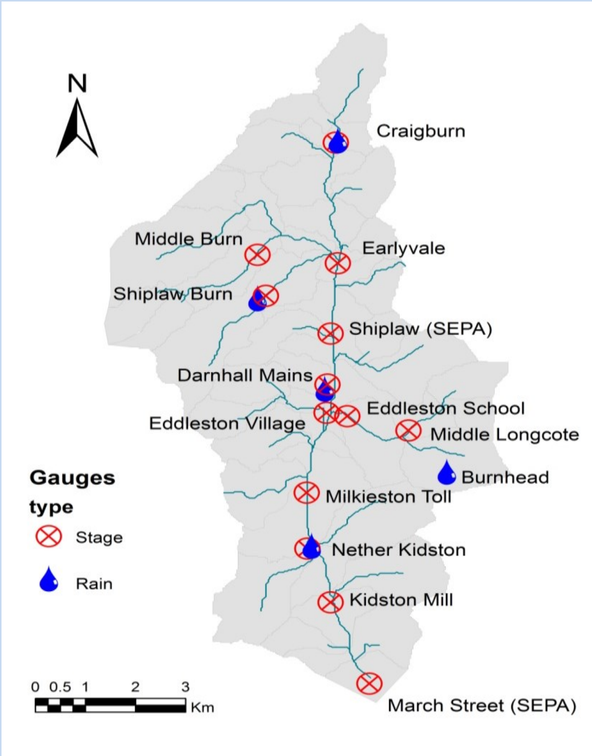
**Example 2: A catchment-scale monitoring approach at Eddleston Water, Scotland**

The catchment of Eddleston Water in Scotland is the subject of a partnership project to investigate the extent to which changes to land use management and restoration of natural habitats can improve the biodiversity in the catchment and reduce the risk of flooding downstream. A range of measures throughout the catchment are planned, including breaching embankments, setting back embankments, creating riparian woodland, re-meandering the river channel, creating ponds and wetlands and blocking ditches with woody debris.

Monitoring was installed prior to the measures to allow two years of baseline data to be collected. Monitoring covered rainfall, river flows and levels, groundwater, hydro-geomorphology, river habitats and aquatic ecology. In order to identify how and where flood runoff is initiated, its conveyance downstream, and the influence of measures throughout the catchment, a detailed hydrometric network was installed. This allows individual flood events to be tracked throughout the catchment.

Modelling has also been carried out, the reinforce the evidence base and to predict the impacts of measures prior to implementation.

(http://www.tweedforum.org/projects/current-projects/eddleston)




## III. Design parameters

Some measures, particularly SuDS, will be constructed to achieve particular design standards and with clear volumetric specifications. In these situations, monitoring of 'retention capacity' as such is unnecessary, because it can be taken from the design parameters. Nevertheless, in terms of the resulting biophysical impacts, there is potential for the downstream effects of such measures to change over time. In some cases the changes over time could be positive, for example as vegetation becomes established in a pond or wetland and increases the potential for retaining pollutants. In others, performance could deteriorate over time, particularly if maintenance is inadequate, if there is significant sediment deposition or active management of outflows is required. Thus, even for measures with design standards, monitoring over time is still a valuable exercise.

## IV. Modelling

Modelling can provide a valuable addition to determining the effectiveness of measures, although modelled results should be treated differently from monitoring or other observations. While models can provide very precise quantification, they are based on a series of qualitative assumptions, and therefore only represent the theoretical response to an interpretation of a system. Nevertheless, there is certainly a place for models in assessing effectiveness, particularly in assessing response that is beyond the scale, in both time and space, of what can be monitored:

- Modelling can allow improved understanding of the response to extreme events (either flood or drought), that may not be captured through a limited period of monitoring. This also, importantly, allows effects to be predicted prior to implementation. This may be necessary for large-scale measures that will significantly influence flood flows in a catchment, where implementation may not be acceptable without modelling to illustrate the anticipated effects (on hydrological parameters) beforehand.

- Modelling can also allow the capture of the ultimate effectiveness of measures that may take years to reach maturity, such as changes to land use. For example, afforestation will take a number of years to achieve its mature state, including interception capacity, water use and changes to soil structure. Where parameters representative of the before- and after-state can be estimated, these can be used in a modelling exercise (this illustrates the point made above, that modelling will require assumptions about what the end-state will be).

- Modelling can allow assessment of effectiveness at a much wider geographic scale than monitoring is likely to achieve. This can extend to the river basin scale or larger, and allows specific consideration of implementation of NWRM, whilst keeping other catchment characteristics constant. In practice, particularly given the small scale of most individual NWRM, basin-scale monitoring may be unable to distinguish the effects of NWRM since there are likely to be so many other factors in play in a catchment, and modelling provides an opportunity by controlling those 'other factors'.

**Example 3: A macro-scale, Pan-European modelling approach for NWRM, JRC (2012)**

This study was carried out by the Joint Research Centre of the European Commission with the support of Stella Consulting. The study considered the effect that NWRM will have on local and regional hydrology using a macro-scale modelling approach that took into account changes in land use involved and the related changes in soil hydraulic properties and area coverage of impermeable surfaces. 12 different policy scenarios were used, addressing changes in forest and urban areas, agriculture practice, and water retention. The scenarios were first run with the Land Use Modelling Platform to determine the spatial distribution of land use classes to be considered, with the resulting maps then used as input to the LISFLOOD hydrological model.

Locally some of the scenarios were estimated to change low flows and flood discharge by up to 20%. For the 21 defined macro-regions in Europe there was a clear difference in the impacts of measures, and for each region the effectiveness of each scenario was ranked in terms of increasing low flow or reducing flood peaks.

(JRC, 2012)

## V. Making best use of existing information

Successfully obtaining quantitative information from new sites where NWRM are installed should, over time, increase the certainty of effectiveness at that individual site, as well as increasing the level of support to encourage uptake of measures more widely. Nevertheless, it will remain challenging to obtain good quality data to cover all measures across a range of climatic and geographical conditions, and it is imperative to establish where implementation can be supported even in the absence of quantification.

Effectiveness can be illustrated with varying degrees of detail. This may vary from:

- Descriptive evidence: narrative and pictorial information. Use of anecdotal information.
- Qualitative evidence: e.g. qualitative ratings to compare against other measures.
- Quantitative evidence: monitoring and modelling approaches as described above.

When considering quantitative evidence in particular, it must be recognised that the effectiveness in a single case cannot necessarily be extrapolated to a similar measure in a different situation. To quantify generalised 'measure effectiveness', it is necessary to accept that a range of values could occur. It is always important to consider the factors that will influence site-specific effectiveness. The potential weight and value of descriptive and qualitative evidence should not be underestimated, particularly in allowing the likely relevance and effectiveness of a measure in different situations to be understood.

It should also be recognised where measures can be considered as 'no-regret', particularly for those that are low-cost and easy to install. For example, rain gardens are considered very much in this light, with implementation of simple rain gardens being possible by homeowners with relatively little technical expertise. In these cases, detailed quantification to prove effectiveness may be disproportionate to the cost of the measure, while still being assured of bringing some level of benefit. Similarly, channels and rills or filter strips can adequately replace rainwater sewers, providing more green space in the city and less water in the sewers with the maintenance being insured by the gardening service of the city.

## VI. List of references

Eddleston Water website, Adaptation Scotland; www.adaptationscotland.org.uk/12/135/0/Eddleston-Water--natural-flood-management.aspx; consulted January 2015

JRC, 2012. Evaluation of the effectiveness of Natural Water Retention Measures – 85