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# Natural Mitigation of Flood Risk

## Overview

- Natural flood management (NFM) can help mitigate the impacts of smaller, more frequent floods and can be a low-cost option for helping to manage flood risk for smaller communities.
- However, as it is not yet proven to mitigate the impacts of extreme flooding or flooding in large catchments, NFM should be used in conjunction with built flood infrastructure.
- NFM delivers many environmental co-benefits, such as carbon storage, water quality protection and biodiversity enhancement, allowing environmental objectives to be addressed simultaneously.
- Successfully implementing NFM requires working in complex multi-stakeholder partnerships, with local communities and land managers participating in decisions.
- Barriers to the implementation of NFM include a lack of public awareness, administrative barriers, and insufficient long-term incentives for land managers.

The UK's flood risk from rivers, surface water and ground-water is projected to increase with climate change. Natural flood management (NFM) can be described as using the natural features of the land to store and slow down the flow of water.[1] NFM is being piloted across the UK and its expansion is an objective of the Government's 25 Year Environment Plan. This POSTnote examines the evidence for the effectiveness of NFM at reducing flood risk, and successful governance approaches to implementing NFM measures.

## Background

Climate change is projected to significantly alter UK precipitation patterns over the coming decades,[2] potentially increasing the severity of extreme rainfall events.[3] The UK Government's 2017 Climate Change Risk Assessment report identified increased flood risk as one of the UK's top climate change risks.[4] In some areas, peak flows (the maximum flow of water at a given point in a river during a flood event) have been increasing at a rate of over 5% per decade.[5] The winter of 2019/20 saw extensive flooding caused by Storms Ciara and Dennis in parts of the UK during the wettest February on record,[6] and a record-breaking number of Environment Agency flood warnings were issued.[7]

NFM is an approach to managing flood risk that aims to create, restore or alter landscape features to reduce flooding (POSTnote 396). It has been highlighted as an important flood mitigation strategy in the 2018 National Infrastructure Assessment and the 2019 draft National Flood and Coastal Erosion Risk Management Strategy for England.[8,9] The Government's 25 Year Environment Plan also aims to expand use of NFM, setting out £15 million of investment into research and implementation between 2018–2021.[10] NFM is being widely piloted in the UK. A 2017 evidence review by the Environment Agency reported on 65 different UK NFM case studies.[11] Measures are currently being applied or considered in over 236 areas throughout the UK,[12] and with sufficient funding this could expand significantly as the UK adapts to increasing flood risks from climate change. Meanwhile, the UK's vulnerability and exposure to flood risk continues to increase. Approximately 10% of new homes are built in high flood risk areas,[13] and over 500 major infrastructure assets are vulnerable to flooding.[3]

## How NFM works

NFM encompasses a range of land management and land use change interventions acting to reduce flood risk through two principal mechanisms:[14]

- **Reducing the volume of floodwater at peak flow.** NFM measures can reduce the volume of floods at peak flow by increasing temporary water storage and infiltration in the

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landscape.[15] Examples include using storage features such as ponds that fill up when waterway levels rise excessively;[16,17] restoring floodplains so that excess water in river channels can spill out into the floodplain to limit damage;[18] or increasing the permeability and storage capacity of soil so that more water infiltrates instead of running rapidly into river channels.[19–21]

- **Slowing and dispersing water flows in landscapes**. NFM interventions, such as revegetating bare peats or planting vegetation along pathways of runoff, aim to increase the 'roughness' of the ground surface to help dissipate and slow the surface flow of water before it enters watercourses. This means water from a rain event arrives at the main watercourse over a longer time period so the river's peak flow is reduced (known as 'attenuation').[14,22,23] In-river features such as leaky woody dams can also slow the flow of the watercourse.[24] These can have the added benefit of altering the timing of peak flows of the separate tributaries feeding a main channel so the flows do not arrive simultaneously, reducing flood risk downstream.[25,26]

## NFM's role in flood mitigation strategies

While NFM has strengths suited to particular contexts, it forms just one part of the wider portfolio of solutions required to address flood risk.[27] Built infrastructure, such as flood barriers, remains essential for protecting vulnerable areas with high population densities (POSTnote 529). NFM is most effective when used in conjunction with other approaches, including household flood resilience measures such as removable flood gates,[28] and altering planning policy to avoid construction in high-risk areas.[29,30] Unlike built flood defences, multiple NFM features need to be implemented throughout the landscape to be effective. Their effectiveness is influenced by their type, design and extent of implementation, so NFM relies on understanding and implementing coordinated actions to address flood risk across the whole catchment (POSTnote 484).

### Strengths of NFM

- **Lower-cost**. Targeted NFM measures can be lower-cost than built infrastructure, so potentially useful in reducing flood risk to smaller communities that might not normally receive investment in built flood defences.[11]
- **Environmental co-benefits**. Unlike most built infrastructure, NFM can bring many co-benefits, such as increasing community social capital,[31,32] biodiversity enhancement,[33] improved water quality,[34,35] and carbon storage.[36] These co-benefits may be significant enough to justify investment in NFM even where the flood mitigation benefits alone do not.[37] NFM measures can help deliver a range of environmental objectives in the Government's 25 Year Environment Plan and other commitments.[38]
- **Climate adaptation**. Climate change is likely to affect existing land use in areas with increasing flood risk. Agricultural production is especially threatened, and in some areas implementing NFM solutions as part of a wider proactive adaptation strategy for land use may generate long-term economic savings.[36,39,40]
- **Enhancing infrastructure resilience.** NFM can enhance the level of protection provided by existing downstream flood defence infrastructure.[41]

### Weaknesses of NFM

- **Uncertainty of effectiveness**. There is greater uncertainty in the level of flood prevention provided by NFM than for built flood defences. Reasons include the reliance on multiple NFM features acting together,[42] and the requirement that they are appropriately maintained.[11] Such uncertainties create challenges in determining which interventions to implement, and where, to achieve a specific level of flood risk reduction. Research efforts are ongoing to improve models and reduce uncertainties.[43]
- **Reductions in effectiveness during prolonged rainfall**. Several widely-implemented NFM measures that aim to temporarily increase landscape water storage (such as storage ponds) can become less effective after multiple rain events, when the ground becomes saturated.[22] This means some NFM measures risk becoming less effective during prolonged rainfall. The same applies to built infrastructure, but the associated risks are easier to estimate.
- **Time lags**. For some NFM measures, flood mitigation properties develop years after implementation. For example, tree planting can mitigate flooding,[44] and emerging research shows that the importance of some key forest processes (such as capturing and evaporating rainwater before it reaches the ground) have previously been underestimated in flood risk models.[45] However, it may take decades for new forests to begin making large contributions to flood risk reduction.[37,46] Other NFM measures can be operational nearly immediately or within a few years,[47] such as storage features or blocking ditches to inhibit water flows.

## Evidence base for flood risk mitigation

The Environment Agency's 2017 NFM evidence review, along with other academic reviews,[27,44] have synthesised the evidence base for NFM (Box 1).[11] Evidence shows that NFM measures can reduce flood risk in smaller catchments (<20km$^2$)[27] or for more common flood events (events with a >10% chance per year),[11] but there is little evidence yet that NFM can do so in larger catchments (>100km$^2$)[27] or for extreme flood events (<1% chance per year).[11] It is uncertain whether this is because NFM is actually unsuitable for mitigating extreme floods or flooding in large catchments, or because insufficient observational evidence currently exists.[48] The evidence gap occurs because conducting observational research over large spatial scales is challenging, and data evaluating the effect of NFM on extreme flooding are scarce because the flood events are, by definition, infrequent.[48]

*Importance of catchment context*

Multiple features need to be implemented simultaneously when NFM is applied in a catchment. The effect of interactions between multiple NFM measures in catchments with complex hydrology is an active area of research.[22,23] Special care must be taken to ensure that multiple features do not end up accidentally increasing flood risks by, for example, synchronising peak flows from different tributaries. Evidence-based modelling (see below) can give an overview of which NFM measures to implement in different locations.[49] However, uncertainty is sufficiently high that these models need to be supplemented with real world observations and local knowledge to ensure the correct NFM measures are implemented.[42,50,51]

**Box 1: Evidence for flood mitigation impacts**
The Environment Agency's 2017 NFM evidence review summarised the evidence for the effectiveness of different NFM features according to the:[11]
- total amount of evidence;
- degree of agreement within the existing evidence; and,
- value of associated social and environmental co-benefits.

**Three common NFM measures**
The review explores a range of NFM measures. Here the evidence for three common NFM features is summarised:[11]
- **Floodplain restoration**. Allowing rivers to spill out onto floodplains when water levels rise can help store large volumes of water during flood peaks.[52,53] Additionally, floodplains tend to have high roughness, so they can slow water flows and attenuate flooding.[18] The review stated that there was low/medium confidence in the effectiveness of floodplain restoration, mostly because there had been few observational studies. A rare example from Norfolk collected data before and after floodplain restoration and found it reduced flood peaks by up to 5%.[54] Co-benefits include enhanced water quality and biodiversity, recreational benefits, and carbon storage.[55,56]
- **Catchment woodland.** Woodland has many flood mitigation properties,[44] including catching and evaporating rainwater into the atmosphere,[45] storing water,[57,58] promoting soil permeability,[59–61] and increasing surface roughness.[62] The review found woodland mitigates flood risk with high/medium confidence, and can generate major co-benefits, notably improving air quality,[63] recreation and carbon storage.[36,64,65] Semi-natural woodland can also enhance biodiversity.[66,67]
- **Landscape storage.** These are dedicated water storage features designed to draw water out of the main channel and temporarily store it during high flows. The review stated that there was medium confidence in their effectiveness, although they require maintenance to remain effective.[11] There is good evidence that they can help with smaller floods.[17,68] For example, in the Holnicote catchment in Somerset, storage features were estimated to be able to reduce peak flows of common (likely to occur once every 5 years) flood events by 25%.[69] However, there is little evidence regarding their effectiveness during extreme flood events, or the impact of networks of storage areas in the same catchment.[22,23]

### Sources of evidence for NFM effectiveness
There are two main sources of evidence for the effectiveness of NFM measures:
- **Observational studies.** These evaluate real-world impacts of NFM features on catchment hydrology (such as river flows). There are few observational studies because of difficulties maintaining long-term research catchments and implementing NFM measures across a large enough area to make a measurable difference to the hydrology.[48] Therefore, research studies tend to focus on smaller catchments.
- **Computer simulations.** Simulation studies attempt to evaluate the effects of NFM measures by modelling the way they change some of the physical parameters in hydrological models (such as the amount of water storage) and how this influences downstream flows.[70] These can be combined with models that can predict flood risks and costs associated with different flood events. The models are based on well-understood real-world physics but are challenging to validate given the lack of observational data.[71]

*Ongoing research*
In 2016, Defra announced £15 million of funding for around 60 NFM projects in the UK, a key requirement being that projects conduct monitoring (results due to be reported in Spring 2021).[72] The Natural Environment Research Council (NERC) also announced a £4 million NFM research programme for 2017–2021, which has funded three projects focusing solely on NFM using leading research methods (Box 2). This suite of projects will further develop the observational and modelling evidence to improve understanding of NFM. Other research councils are also funding NFM research, such as ESRC on participatory approaches to modelling flood risk.[73]

## Evidence for effectively implementing NFM
Implementing NFM requires the cooperation and coordination of communities and land managers across a catchment, which is a complex governance challenge. NFM has the potential to provide communities with a sense of agency in tackling flood risk,[74,75] and can help create social capital within communities.[32] However, as with conventional infrastructure, NFM can undermine community confidence in institutional responses to mitigating flood risk if imposed without sufficient engagement, or if not perceived to be part of a coordinated catchment flood management plan.[74,76–78] The past few years of NFM implementation have seen practitioners and researchers gain considerable practical experience in real-world implementation, helping develop the evidence base for what makes NFM projects successful and on implementation barriers.[31]

### Coordinating efforts through partnerships
Successful projects tend to bring together partnerships of multiple organisations and landholders across catchments, with project staff and facilitators dedicated specifically to managing these partnerships and linking together planning at local and national scales.[32,79,80] Such partnerships can support NFM by:
- Creating catchment management plans for enhancing the strategic planning of NFM, which can help coordinate the land management activities of different actors to ensure they are complementary,[80] and clarify each actor's responsibilities for implementing certain NFM measures (POSTnote 484). In theory, these can also help optimise the simultaneous delivery of multiple local objectives, such as flood mitigation and biodiversity and water quality enhancement.[81] However, the relatively small scale of NFM implementation to date has constrained how well it has delivered across multiple objectives.
- Providing relevant, locally specific information on NFM to stakeholders. Stakeholders are more likely to engage effectively with information that is clearly adapted to their local context.[82]
- Draw on a broad range of expertise from different project partners, which can help with tasks such as attracting additional funding for NFM measures.[81]

### Participatory approaches to decision-making
Community satisfaction with NFM projects is often higher if measures have been implemented through more democratic decision-making processes, rather than consulting communities after solutions have already been planned by authorities.[78,83] Participatory approaches include listening to and addressing

**Box 2. UKRI NERC NFM Projects**
NERC is funding three major NFM research projects,[84] due to report on outcomes in 2021. These projects are collecting real-world observational data to improve modelling and reduce uncertainties about NFM impacts on flood risk.

**Landwise NFM**
Focusing on the Thames catchment, this project is evaluating the flood risk impacts of land management practices (including effects of agriculture and woodland management on soil conditions) in lowland catchments.[85] Hydrology in lowlands tends to be complicated by higher water tables, urbanisation and river channel controls. Other novel contributions include using soil moisture data gathered by satellites to better model catchment hydrology and flood risk, and developing techniques to integrate local knowledge into hydrological models.

**Protect NFM**
This project focuses on evaluating the flood benefits of upland restoration and land management practices, including peatland restoration and revegetation, tree planting and ditch blocking.[86] It is using real-world controlled experiments to develop more robust estimates of NFM impacts than can be inferred from conventional monitoring schemes.[47] In addition, the project is developing freely available models for predicting the impacts of multiple NFM features being implemented simultaneously.

**Q-NFM**
This project in Cumbria is predominantly focused on developing the evidence base for the effectiveness of NFM in large catchments.[87] It is conducting a systematic review of experimental evidence for the impact of NFM measures on hydrology, and supplementing this with detailed in-field monitoring of the impacts of NFM measures in experimental sites. A key aim of the project is to help quantify and reduce the uncertainty in parameters that are used in hydrological models to represent the impacts of NFM features. This will facilitate the improvement of models to support NFM implementation in large catchments.

people's local water management concerns, through to incorporating local knowledge in the hydrological models used to identify potential NFM solutions.[50,88] These help foster a sense of engagement, and implement actions that give the community greater agency over their flood risks.[32] Such approaches also recognise that there is no one-size-fits-all solution to successful NFM implementation, and each catchment requires implementation strategies suited to the local context.[80] NFM practitioners observe that the strongest determinants of where NFM measures are implemented in practice are social factors, rather than areas identified through modelling.[89] Participatory processes require considerable and prolonged investments in community engagement.[81] Where trust of statutory authorities may be low, it may be necessary to use trusted intermediaries to lead engagement, such as local or national environmental or flooding-related NGOs.

## Barriers to implementation of NFM
For NFM to make a large contribution to reducing the UK's flood risk under climate change, implementation will have to be at a much greater scale than has been piloted so far, coupled with appropriate spatial targeting and selection of NFM measures. Multiple barriers to implementation have been identified.

*Incentivising land managers*

- **Lack of awareness of NFM**. There remains a widespread lack of awareness and understanding about NFM. For example, a Scottish study found 59% of farmers had very limited knowledge of NFM and the role it can play.[76]
- **Concerns with changing land use.** While some forms of NFM (such as improved soil management) can be implemented with minimal impact on productivity,[40] there are cultural and economic barriers to implementing other forms of NFM. Resources need to be made easily accessible to overcome these.[76,90] Several experts suggested that the Government's proposed Environmental Land Management schemes (ELMs) could be a source of funding for NFM implementation. Landowners under ELMs will be paid for various environmental benefits provided by their land (POSTnote 627). However, current proposals are unclear as to the degree to which financing will pass to landowners versus tenant farmers, which risks failing to incentivise the direct land managers. Also, contract durations need to provide enough incentive for land managers to bring land out of production to implement some types of NFM.
- **Responsibility for maintenance**. Land managers may also be unwilling to implement NFM if they bear the burden of long-term liability for maintenance, particularly if the measures are designed to reduce flood risk elsewhere in the catchment.[76,91] There are no government funding schemes available specifically for NFM maintenance and it is often unclear who should be responsible for maintenance of NFM features for which long-term management is an ongoing requirement.[77,91]

*Administrative barriers*

- **Appraisal of costs and benefits for NFM investments**. The current approaches to assessing costs and benefits outlined in the Treasury's Green Book were primarily designed for built infrastructural solutions. As a result, NFM solutions do not fit neatly into existing processes, creating a funding barrier. Approaches to estimating the benefits of NFM measures may also take insufficient account of non-flooding co-benefits.[37] While problems are partially addressed by Defra's 2020 changes to partnership funding,[92] substantial changes to existing approaches may require a shift in agencies' organisational cultures.[78]
- **Planning processes**. Implementing NFM solutions can sometimes require the same planning processes and public consultation as conventional infrastructure does. Such a barrier could be reduced by allowing the installation of NFM features to go through bespoke planning processes.[69]
- **Lack of statutory requirement to implement NFM**. Local authorities have an important role to play in implementing catchment-scale solutions, but there are often skills and resource shortages. In addition, a complex water governance approach hinders a clear allocation of responsibility amongst institutions. As NFM solutions do not fall within English bodies' statutory duties, they may be deprioritised when financial resources are scarce.[91] However, NFM features require sustained commitment to monitoring, and sometimes maintenance, for their ongoing effectiveness.

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