East Lothian Council

REPORT TO: East Lothian Council

MEETING DATE: 31 October 2023

BY: Executive Director for Place

SUBJECT: The Eddleston Water Project Site Visit to Explore Natural Flood Management

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1 PURPOSE

1.1 To present to East Lothian Council the lessons learned report prepared by the Musselburgh Flood Protection Team which reports on the Scottish Government's Eddleston Water Natural Flood Management Research Project, and the evolved position on Natural Flood Management (NFM) within the Musselburgh Flood Protection Scheme (the Scheme).

1.2 To comply with the instruction of the Motion approved at a meeting of Council in August 2023, which requested that *the scientific report from the Eddleston Water site visit to explore Natural Flood Management* is brought to a full Council meeting *to allow Members to read, debate and note* the contents.

1.3 To recommend to Council new actions that are considered the best way to advance Natural Flood Management and Nature-Based Solutions (NbS) over the long-term in the River Esk catchment.

2 RECOMMENDATIONS

2.1 It is recommended that Council:

a) Notes the content of the lessons learned report from the Eddleston Water site visit to explore NFM, which is provided in Appendix 1.

b) Agrees that further investigation of the potential for NFM measures in the River Esk catchment is undertaken through a new action on the Local Flood Risk Management Plan (Forth Estuary) processes and not the Scheme.

c) Encourages and supports the formation of a new independent body or equivalent, like Tweed Forum, for the River Esk catchment, which would be capable advancing both NFM and NbS for the relevant local

authorities, the regulatory organisations, other interested organisations, and community groups within that area of interest.

d) Notes that the Scheme will continue to develop an Outline Design that includes maximum NbS as part of the design of the new physical defences in Musselburgh. This process is currently part of the ongoing Environmental Impact Assessment (EIA) process which is being undertaken and will include for all new obligations deriving from NPF4 (National Planning Framework 4) which was published in early 2023.

3 BACKGROUND

3.1 The town of Musselburgh has a very significant flood risk due to its geographic location: i.e. it has been built on the natural flood plains of the River Esk and the Firth of Forth. There have been three major flood events from the River Esk in the modern period – 1891, 1927 and 1948. The River Esk was re-engineered through the length of the town in the years immediately after the 1948 event. The level of flood risk to the town is projected to become much larger due to the impacts of climate change.

3.2 Musselburgh Flood Protection Scheme (the Scheme) is being promoted by East Lothian Council (ELC) under the Flood Risk Management (Scotland) Act 2009 (the Act). Jacobs was appointed by ELC in December 2017 to develop a flood protection scheme for Musselburgh to reduce flood risk from all sources of flooding. The project is being delivered in stages under PRINCE2 Project Management principles and is currently in its Stage 4 which is known as ‘the Outline Design’.

3.3 The scope of the project required Jacobs to consider natural, sustainable and catchment flood risk management options from the outset. An initial report was produced during Project Stage 2 (known as ‘the Review of Existing Studies’) and a further assessment was completed during Project Stage 3 (known as ‘The Options Appraisal Process’) supplemented this. These reports fed into the overall Options Appraisal Process in the ultimate determination of the ‘Preferred Scheme’.

3.4 The Scheme’s design has been advanced through an extensive consultation process with regulatory organisations, key stakeholders, community groups, businesses, and the people of Musselburgh. Throughout the Scheme’s consultation process, the project team has been asked by members of the public to identify and include more natural solutions within the Scheme’s design. Whilst Jacobs (2019, 2020) had considered the feasibility and effectiveness of such measures for delivering flood risk reduction within the Scheme, during consultation events in February 2022 East Lothian Council committed to exploring this further.

3.5 In January 2020 a ‘Preferred Scheme’ was approved by a meeting of East Lothian Council’s Cabinet. This ‘Preferred Scheme’ was a concept design based on the considered best combination of flood risk management options through which Musselburgh could have its substantial flood risk

reduced to an acceptable level. This was at the end of Project Stage 3. At this time, after a comprehensive Options Appraisal had been completed, the project team had concluded that Musselburgh could not be protected without new physical defences in the town, and that the 'Preferred Scheme' contained the maximum number of substantial natural and sustainable flood risk management options in the catchment that were deliverable within the Scheme.

3.6 The Scheme is currently within its Project Stage 4 and is developing an Outline Design which will be presented to a meeting of full Council in January 2024. This Outline Design still contains the significant Sustainable Flood Risk Management measures that were originally included in the 'Preferred Scheme' in January 2020. Specifically, these are: (i) the modification of Rosebury Reservoir to store large volumes of water during a flood event; (ii) the modification of Edgelaw Reservoir to store large volumes of water during a flood event; and (iii) the provision of a new large-debris catcher by Whitecraig. It is highlighted that, based on our current understanding, these sustainable engineering measures will contribute more to reducing flood risk in Musselburgh, than if wholescale NFM measures were delivered across the c.330km^2 of the River Esk catchment.

3.7 This Scheme is being designed within a period of substantial change in our understanding of the emerging Climate Crisis. This is particularly relevant to a flood protection scheme as it is currently understood that increase in flood risk will be the single greatest risk to Scotland deriving from climate change. The Scheme has therefore absorbed any requirements from ELC having accepted the Climate Crisis, and its Climate Change Policy. The Scheme has also fully considered the new (and substantially greater) climate change projections deriving from UKCP18: the Scheme's position on this was accepted by a meeting of council in October 2022.

3.8 As confirmed by the meeting of Council in October 2022, the project team is ongoing in developing an Outline Design, whilst simultaneously finalising the level of flood risk reduction (also known as the Scheme's Standard of Protection) that will be provided to Musselburgh through the Scheme. This work is not complete and will not be reported to Council until January 2024; however, it is highlighted that under no circumstances will Musselburgh have its flood risk completely removed as Musselburgh will continue to remain on the natural flood plains after the Scheme is delivered. There will always remain a risk of a larger flood event than the Scheme protects against, and all indications are that climate change will make future flood risks worse. Therefore, this report highlights that continued work on natural flood management in the River Esk catchment will be the best way to continue to reduce that future flood risk once the Scheme is completed.

3.9 Further to the desire of the public to see the Scheme include more NFM in the project (as highlighted in Section 3.4 of this report), and the considered position of the project team (as highlighted in Section 3.8 of this report) work continued to explore the potential for additional natural and sustainable flood risk management options in the Esk Catchment after the Cabinet meeting in January 2020. It is highlighted that the following activities are some notable activities in this process:

a) Engagement with the Scottish Government's NFM Research Project Team who are delivering the Eddleston Water project;

b) Development of a partnership working arrangement with 'Dynamic Coast', who are a new governmental organisation tasked with developing an understanding of Scotland's Coastal Change;

c) Engagement with individuals and organisations across the River Esk catchment to identify potential new NFM options that could be included for delivery within the Scheme;

d) Consideration, and inclusion if appropriate, of both NFM and NbS solutions within the Outline Design through the advancement of the EIA; and

e) Development of the parallel new Musselburgh River Restoration multiple-benefit project further to the instruction of the Council meeting of August 2022.

3.10 On 29 August 2023 a motion was approved by Council to bring forward "The scientific report from the Eddelston Water site visit to explore Natural Flood management" to a future Council meeting to allow Members to read, debate and note the contents".

3.11 The report contained in Appendix 1 was produced by Jacobs on behalf of ELC and represents a "Lessons Learned about NFM from the Eddleston Water project". Further details of The Eddleston Water project are contained within section 3.14-3.17 of this report.

3.12 The Jacobs report is based on several references, the key ones being independent research reports produced by Tweed Forum and the University of Dundee on behalf of the Eddleston Water project. These are independent reports and the "lessons learned" are based upon those findings and the knowledge imparted on ELC (and others) at the site visit.

3.13 The Eddleston Water project has produced several scientific reports on NFM, based on their work in the catchment; these reports, alongside the site visit, have been used as the basis of the Jacobs "Lessons Learned" report. The conclusions from the 2021 Eddleston Water Report form a key part of the conclusions within the Jacobs report and recommendations within this Council report.

The Eddleston Water NFM Scientific Research Project

3.14 The Eddleston Water project was started in 2009 by the Scottish Government, SEPA and Tweed Forum, to assess the effectiveness of NFM as a means of delivering flood risk reduction and habitat improvement on a catchment scale. Tweed Forum is the project manager, and along with Scottish Government, SEPA and Scottish Borders Council, they form the Project Board. The University of Dundee was commissioned by the project in 2010 to produce a scoping study, and together with the British Geological Survey, have been the main scientific providers to the project since then.

3.15 The Eddleston Water catchment is 69km^2 in size, and the measures implemented by the project include:

- Planting 330,000 native trees;
- Constructing 115 high-flow log structures;
- Re-meandering 3.5km of river channel; and
- Constructing 38 flood storage ponds.

3.16 A comprehensive network of monitoring was established before the measures were implemented, to facilitate a before-and-after assessment of the effectiveness of each type of measure. This was combined with fixed point photography and topographic surveys to assess physical and biological changes within the river corridor during the same period. Tweed Forum (2017 and 2022) provided updates on the outcomes of the research so far.

3.17 A combined hydraulic and hydrological catchment model was developed for the project, using open-access HEC-RAS software. This has recently been upgraded to the latest version and could assist both the transferability of results and scaling-up to other catchments.

The Eddleston Water Project – Lessons Learned Conclusions Relevant to Eddleston Water

3.18 Detailed hydraulic and hydrological modelling of the NFM measures constructed on the Eddleston Water project has indicated a 5% reduction in peak flows at downstream receptors, thereby demonstrating their effectiveness against flood events on a catchment of 69km^2.

3.19 The ability to construct those measures has depended upon the voluntary agreement of multiple landowners.

3.20 Further to Section 3.19 of this report, the ability to reach those agreements, and thus deliver the project, has relied upon the involvement of an ‘honest broker’ with detailed knowledge of farming practices and the individuals involved.

3.21 The reduction in peak flow was not known in advance, and funding was not conditional upon quantifying this during the design phase.

The Eddleston Water Project – Lessons Learned Conclusions Relevant to The Scheme

3.22 NFM has a role to play in flood risk management generally when combined with engineered methods as part of a whole-catchment approach to reducing flood risk. It may also be capable of delivering other desirable NbS outcomes.

3.23 While NFM on the Eddleston Water project has been demonstrated to reduce peak flows by 5% on a 69km^2 catchment, the Scheme would require a 50% reduction in the peak flow of the River Esk (330km^2

catchment) to avoid the need for physical defences during a present-day 0.5% AEP Flood Event (which is also known as the 1 in 200 Years Flood Event). A 5% reduction would facilitate only a minimal reduction in the required flood defence heights.

3.24 The approach to implementing NFM measures taken by the Eddleston Water project may be incompatible with the approach to developing a flood protection scheme under the Act. Voluntary agreements with landowners may introduce various legal risks. Implementing NFM measures with no quantifiable reduction in flood risk at the time of design may introduce funding and design liability risks.

Advancing NFM in the River Esk Catchment

3.25 As detailed in Section 3.2 - 3.10 of this report, the Scheme has worked from its earliest state to deliver natural, sustainable, and catchment-based flood risk management measures to reduce the flood risk to the town of Musselburgh. The Scheme included substantial sustainable flood risk management measures within the 'Preferred Scheme' that was approved by ELC Cabinet in January 2020.

3.26 The Scheme will continue to work to design an environmentally acceptable Outline Design, and that it continues to aspire to include as many NbS and 'green-blue' infrastructure as possible within those designs.

3.27 The Scheme will continue to advance the parallel multiple-benefit project known as Musselburgh River Restoration within the Scheme's project timeframes. Thereafter any aspiration to continue to advance that project and its aims would need to be carried on by ELC through a separate delivery channel.

3.28 The scheme is of the view that formal recognition is made of the fact that Musselburgh cannot have its substantial flood risk reduced to an acceptable level without the provision of new physical defences in the town. Furthermore, that it is not reasonable to continue to strive to deliver more NFM measures within the Scheme given the inability of the project team to identify any further measures between 2020 and 2023 and the conclusions summarised in Section 6 of this report.

3.29 Given the projected increase in flood risk that climate change will bring to Scotland, as detailed in Section 3.7 of this report, that ELC continue to advance NFM research and option identification and delivery in the River Esk catchment. This is considered to be essential to build on the levels of flood risk reduction being delivered through the Scheme. This is considered to be part of a managed adaptive approach for Musselburgh in relation to climate change and in accordance with the Scottish Government's current policy approach.

3.30 It is considered that further investigation of the potential for NFM measures in the River Esk catchment should be undertaken through a new action on the Local Flood Risk Management Plan (Forth Estuary) processes. That this would be best delivered independently of the Scheme so that the timescales associated with achieving landowner agreement and baseline

monitoring do not delay the Scheme's ability to proceed with protecting Musselburgh from the present-day flood risk.

3.31 It is considered that ELC encourages and supports the formation of a new independent body or equivalent, like Tweed Forum, for the River Esk catchment, which would be capable advancing both NFM and NbS for the relevant local authorities, the regulatory organisations, other interested organisations, and community groups within that area of interest.

3.32 In addition to NFM, the use of NbS within the Scheme will continue to be fully leveraged to deliver as many other positive outcomes as possible in the catchment, within the river corridor in Musselburgh, and along the Musselburgh coastline. Such outcomes could include biodiversity enhancement, fish passage improvement, increased water quality and habitat creation. This approach is consistent with the ethos of Scotland's recently published National Planning Framework 4 (NPF4), (Scottish Government, 2023).

4 POLICY IMPLICATIONS

4.1 The Act places a statutory responsibility on the local authority to exercise their flood risk related functions with a view to reducing overall flood risk. A key responsibility for ELC is the implementation of the flood risk management measures in the Forth Estuary Local Flood Risk Management Plan.

4.2 The Scheme will contribute towards the East Lothian Plan 2017-27, focusing on health and wellbeing, safety, transport connectivity, sustainability and protecting our environment.

4.3 The Scheme will support the Council's Climate Change Strategy; however, it is highlighted that this project is an 'adaptation' project due to implications of climate change on Musselburgh.

5 INTEGRATED IMPACT ASSESSMENT

5.1 The Scheme will undergo Integrated Impact Assessments during its development.

5.2 A Preliminary Environmental Appraisal Report (PEA) was undertaken during Project Stage 3 (the Outline Design), and this was included in the Preferred Scheme Report presented to Cabinet in January 2020.

5.3 The Scheme will undertake an Environmental Impact Assessment (EIA) on the Outline Design. This will be completed alongside the Outline Design before an update is presented to Council in January 2024.

6 RESOURCE IMPLICATIONS

6.1 Financial –

(a) All costs associated with the development of this report and its appendices will be absorbed through the total Scheme costs of the flood protection scheme.

(b) The Scheme is authorised under the Scottish Government's flood protection scheme programme. The Project Team and thereby the Council update the Scottish Government every autumn on the updated estimate for the Total Scheme Cost and its Spend Profile. From this data, and in line with the authorised programme, the Council receive the 80% contribution on an annual basis as part of the capital grant settlement.

6.2 Personnel - None

6.3 Other – None

7 BACKGROUND PAPERS

7.1 Report to Cabinet in May 2016 – approval of the Local Flood Risk Management Plan (Forth Estuary) which included a proposed flood protection scheme for Musselburgh.

7.2 Report to Cabinet in January 2020 – approval of the 'Preferred Scheme' concept to be advanced to an Outline Design.

7.3 Report to Council in August 2022 – Musselburgh Flood Protection Scheme: Update on Scheme Development.

7.4 Report to Council in October 2022 Musselburgh Flood Protection Scheme – Update on Scheme Development.

7.5 Eddleston Water Report 2021

7.6 Motion to Council, 29 August 2023: approval to bring forward 'The scientific report from the Eddelston Water site visit to explore Natural Flood management'

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DATE	31 Oct 2022

Lessons learned about Natural Flood Management from the Eddleston Water project

Date:	6 September 2023
Project name:	Musselburgh Flood Protection Scheme
Project no:	701909CH
Attention:	Conor Price
Company:	East Lothian Council
Prepared by:	Jim Baxter
Reviewed by:	Kirsteen Nixon
Document no:	701909-JEC-S4-XXX-XXX-TN-Z-0007
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Introduction

Musselburgh Flood Protection Scheme (the Scheme) is being promoted by East Lothian Council (ELC) under the Flood Risk Management (Scotland) Act 2009 (The Act). Jacobs was appointed by ELC in December 2017 to develop a scheme for Musselburgh to reduce flood risk from all sources of flooding. The project is being delivered in stages under PRINCE2 Project Management principles and is currently in Stage 4 Outline Design. The scope of the project required Jacobs to consider natural, sustainable and catchment flood risk management options from the outset. An initial report was produced during stage 2 and a further assessment during stage 3 supplemented this.

Throughout the Scheme's consultation process, the project team has been asked by members of the public to identify and include more natural solutions within the Scheme's design. Whilst Jacobs (2019, 2020) had considered the feasibility and effectiveness of such measures for delivering flood risk reduction within the Scheme, during consultation events in February 2022 the project team committed to exploring this further. The purpose of this technical note is therefore to summarise the insight gained by visiting the Scottish Government's national Natural Flood Management (NFM) research project on the Eddleston Water, near Peebles, on 31st March 2023. During the visit the project team talked extensively with the scientific experts responsible for its delivery.

The site visit was attended by the following people:

Individual	Project affiliation	Organisation	Role
Shona McIntosh	Musselburgh FPS	ELC	Councillor for Musselburgh Ward
Ian Chalmers	Musselburgh FPS	ELC	Senior Flood Officer
Conor Price	Musselburgh FPS	CPE Consultancy	Scheme Senior Project Manager
Jim Baxter	Musselburgh FPS	Jacobs	Scheme Project Delivery Manager

Individual	Project affiliation	Organisation	Role
Jaqueline Parker	Musselburgh FPS	-	Musselburgh Stakeholder
Roger Crofts	Musselburgh FPS	-	Musselburgh Stakeholder
Simon Shackley	Musselburgh FPS	-	Musselburgh Stakeholder
Ian Pattison	Musselburgh FPS	-	Musselburgh Stakeholder
Ann Stuart Kmicha	Musselburgh FPS	Dalkeith & District Community Council	Musselburgh Stakeholder
Chris Spray	Eddleston Water project	Tweed Forum and University of Dundee	Science Manager; Policy & Practice Specialist
Andrew Black	Eddleston Water project	University of Dundee	Hydrology Specialist
Alan Werritty	Eddleston Water project	University of Dundee	Science & Policy Specialist
Duncan Morrison	Eddleston Water project	Scottish Borders Council	Flooding Team Leader
Paul Grigor	Eddleston Water project	Scottish Borders Council	Flooding Engineer
Roy Richardson	Eddleston Water project	SEPA	Chairperson of Eddleston Project Board

Figure 1: Site visit participants viewing a length of engineered meander on the Eddleston Water

Terminology

During the Scheme's consultation, it became apparent to the project team that many terms are used interchangeably by professionals and the public to refer to 'natural' efforts to reduce flood risk. These terms include but are not limited to, 'natural solutions', 'nature-based solutions', 'natural flood management', 'sustainable flood management', 'working with nature', 'nature-based features', 'engineering with nature', and 'natural & nature-based features' etc. All the terms share similarities, but it is possible to highlight that there are also relevant distinctions between them. For the purposes of this technical note, the terms Nature-based Solutions (NbS), Natural Flood Management (NFM) and Sustainable Flood Management (SFM) have been used.

The Nature-based Solutions Initiative (2023) defines NbS as, "working with nature to address societal challenges, providing benefits for both human well-being and biodiversity". Examples of NbS may include sustainable management of forests, wetlands, and farmland. Positive outcomes of NbS could include biodiversity enhancement, fish passage improvement, increased water quality and habitat creation.

The NFM Network Scotland (2023) defines NFM as, "a catchment-scale technique that involves working with natural features and processes to manage the sources and pathways of floodwaters... restoring the natural capacity of a catchment to slow or store floodwater". NFM is therefore a form of NbS, but not all NbS will deliver flood risk reduction. Examples of NFM may include river meandering, online storage, offline storage, and tree planting. These measures may also deliver other positive NbS outcomes besides flood risk reduction.

SFM, though less well defined, is considered to mean reducing flood risk to downstream receptors through the sustainable use (and reuse) of the natural and built landscape, and its raw materials. An example of this within the Scheme is the modification of two existing reservoirs in the South Esk catchment to reduce flood risk in Musselburgh. This was proposed during the Scheme's Stage 3 Options Appraisal and was included within the Preferred Scheme published in January 2020.

Background to the Eddleston Water Project

The Eddleston Water project was started in 2009 by the Scottish Government, SEPA and Tweed Forum, to assess the effectiveness of NFM as a means of delivering flood risk reduction and habitat improvement on a catchment scale. Tweed Forum is the project manager, and along with Scottish Government, SEPA and Scottish Borders Council, they form the Project Board. The University of Dundee was commissioned by the project in 2010 to produce a scoping study, and together with the British Geological Survey, have been the main scientific providers to the project since then.

The Eddleston Water catchment is 69km^2 in size, and the measures implemented by the project include:

- Planting 330,000 native trees
- Constructing 115 high-flow log structures
- Re-meandering 3.5km of river channel
- Constructing 38 flood storage ponds

A comprehensive network of monitoring was established before the measures were implemented, to facilitate a before-and-after assessment of the effectiveness of each type of measure. This was combined with fixed-point photography and topographic surveys to assess physical and biological changes within the river corridor during the same period. Tweed Forum (2017 and 2022) provided updates on the outcomes of the research so far.

A combined hydraulic and hydrological catchment model was developed for the project, using open-access HEC-RAS software. This has recently been upgraded to the latest version and could assist both the transferability of results and scaling-up to other catchments.

Discussion about lessons to be learned from the Eddleston Water Project

The Scheme's project team, the Eddleston Water project team, and a selection of Musselburgh stakeholders met on 31st March 2023. The day consisted of both discussion sessions and a site visit to parts of the Eddleston Water project. The following is Jacobs' interpretation of those discussions:

What flood risk reduction did the project set out to achieve and has it been successful in this respect?

As a research project, the team did not set specific performance criteria or thresholds for success with respect to flood risk reduction.

Instead, the aim was to assess the effectiveness of a variety of different NFM measures in terms of flood risk reduction and habitat restoration. The results indicate that some of the measures reduced flood risk to downstream receptors, as might be expected. Other measures demonstrated no discernible reduction in flood risk but delivered other positive outcomes such as increased biodiversity.

Which NFM measures have been effective in reducing the peak flow in the river and what percentage reduction has been attributable to each of the different measures constructed?

Studies of channel re-meandering in the Eddleston main valley show no significant change in downstream flood risk. This may be partly attributable to flood banks which prevent the escape of water onto the floodplain in some areas. However, there was a substantial improvement in biodiversity at the location of the meanders.

The evidence also demonstrates that large floodplain storage ponds, as well as engineered log structures, increased the lag time between rainfall in the catchment and rising water levels downstream. This indirectly suggests a reduction in flood risk to downstream receptors.

Tree planting appeared to improve infiltration where the prevailing ground conditions were low in permeability, but the benefit was less discernible where the soil was already more permeable. Increased infiltration in the catchment can often be associated with reduced flood risk downstream.

Considering the Eddleston catchment as a whole, a modelled representation of a variety of NFM measures, including headwater flow deflectors and the managed increase of floodplain storage, showed that reductions in flood peak flows of 5% could be expected at all return periods that were analysed, up to 1 in 1000 years.

What other factors influence the effectiveness of the NFM measures implemented?

The location of the NFM measures within the catchment is critical to their effectiveness.

Where they are constructed in the upper catchment then there is still a substantial uncontrolled catchment below them and therefore the reduction in flood risk to downstream receptors is limited. Equally, where they are constructed furthest downstream then the catchment is not used efficiently. In this case, the peak flow reaching the NFM measures will be larger, and the measures are more likely to be overwhelmed during a larger flood event. It could therefore be considered that, for NFM to be most effective, measures need to be implemented on a whole-catchment basis rather than within selected parts of it.

All the measures in the Eddleston Water catchment were constructed with the voluntary cooperation of the landowners. Many of the optimal locations identified through the extensive modelling and assessment exercise could not be used because of their value to the farmer or landowner, for uses such as prime agricultural land. This meant that measures were constructed elsewhere, where an agreement could be reached, often resulting in sub-optimal outcomes.

Could the NFM measures constructed be scaled up for larger catchments and more extreme return periods, and are there any limitations to this?

It is considered by some (Dadson et al, 2017) that NFM is most effective against small flood events on small catchments, while others (Hankin et al, 2021) concluded that NFM effects are scale-dependent.

During large flood events, it may become more likely for individual NFM measures to be 'drowned out' by the increased flow. As the flow spills into the wider floodplain, the individual NFM measure is bypassed, and its effectiveness is reduced. It is therefore unlikely that NFM measures could deliver a greater reduction in peak flow than has been demonstrated for small flood events.

On large catchments, the NFM measures used on the Eddleston Water project could also be implemented. However, a larger catchment such as the River Esk (330km^2 in size) would require a greater number of individual measures to deliver a comparable reduction in peak flow to the Eddleston Water project (69km^2 catchment size). The effectiveness of NFM on a larger catchment would therefore depend upon securing enough locations with landowners' agreement, and enough of those NFM measures being sufficiently effective to deliver the desired reduction in peak flow.

Furthermore, there is a risk of uncertainty around scaling up natural flood management measures proportionally, for example to the Esk. Enhancing storage could potentially have the effect of synchronising runoff response particularly in a large regional-scale event. This could have un-intended negative consequences.

Could NFM be a viable alternative to traditional engineered methods of flood risk reduction?

There is evidence that NFM is a viable flood risk management technique against small flood events on small catchments but its demonstrable effectiveness against large flood events on large catchments remains unproven.

NFM has a place within flood risk management and in providing a range of other benefits; these include enhancing wildlife and fisheries, improving water quality, increasing recreation opportunities, and carbon management. NFM by itself is insufficient when large reductions in peak flow are required to meaningfully reduce flood risk to downstream receptors. Rather than an alternative to engineered methods, NFM should be seen as complimentary to them when working with landowners to take a whole catchment approach to reducing flood risk.

What challenges might be associated with incorporating NFM within a flood protection scheme under the Flood Risk Management (Scotland) Act 2009?

The Tweed Forum was instrumental in the successful delivery of the Eddleston Water project, and without them no NFM measures would have been implemented. They acted as an 'honest broker' between the project and individual farmers and landowners. Their detailed knowledge of farming practices and individuals was essential to understanding what measures and locations would be acceptable to both parties.

All the landowner agreements were reached voluntarily on a basis of trust, without contracts or payment between the parties. This approach would likely be incompatible with the legal aspects of the Act, which would make it a criminal offence to modify or remove NFM measures in the future without the permission of the local authority. In contrast, on the Eddleston Water project the farmer or landowner could, in theory, remove the NFM measures if they no longer wished to participate.

Another challenge for a Scheme delivered under the Act would be demonstrating the flood risk reduction attributable to specific NFM measures at the design stage to justify funding their construction. There are still many uncertainties associated with modelling the effectiveness of NFM measures, not least the deliverability at the optimal locations identified. The Eddleston Water project used empirical evidence to assess the effectiveness of various measures, meaning the reduction in peak flow was not known until after the measures were constructed and monitored for a prolonged period. In some cases, certain measures failed to contribute to a reduction in flood risk.

For this reason, it would be impracticable to use NFM measures to offset the required height of physical defences at a downstream receptor. Without knowing in advance how much the NFM measures would reduce peak flow, there would be no way of determining how much to reduce the height of defences by.

Furthermore, the effectiveness of specific NFM measures could vary from one catchment to another depending on environmental factors such as topography, ground conditions, and surrounding land use. An effective catchment-wide NFM strategy to deliver a defined reduction in flood risk to downstream receptors would likely require long-term monitoring of the effectiveness of individual measures. This would have to be combined with the ability to add, modify, or replace individual measures depending upon the measured outcomes. A funding mechanism for such work aligns more with a maintenance programme than with a discrete capital works project such as a flood protection scheme.

What actions might help increase the use of NFM as a form of flood risk reduction in Scotland?

As a research project, the Eddleston Water project was funded through a variety of local, national and EU funding schemes, not necessarily tied to delivering flood risk reduction. NFM has significant potential to deliver other NbS outcomes such as carbon sequestration. Generating revenue streams derived from such outcomes could be an effective model for funding long-term maintenance of NFM measures if that income was shared equitably with the landowner.

On the Eddleston Water project, prospective farmers and landowners were swayed into participating more by the participation of their neighbouring landowners than by scientific models or academia. Ensuring that they did not lose financially was a key consideration, and therefore critical to the ability to deliver NFM at a catchment scale.

Finally, since the reduction in peak flow attributable to NFM measures is not yet reliably quantifiable during design, NFM would be more suited to offsetting future increases in flood risk due to the effects of climate change rather than protecting against a defined present-day flood risk. This is because both the effectiveness of the NFM measures and the future flood risk attributable to the effects of climate change would be uncertain at the time of construction.

Conclusions relevant to the Eddleston Water Project

Detailed hydraulic and hydrological modelling of the NFM measures constructed on the Eddleston Water project has indicated a 5% reduction in peak flows at downstream receptors, thereby demonstrating their effectiveness against flood events on a catchment of 69km^2. The ability to construct those measures has depended upon the voluntary agreement of multiple landowners. The ability to reach those agreements, and thus deliver the project, has relied upon the involvement of an 'honest broker' with detailed knowledge of farming practices and the individuals involved. The reduction in peak flow was not known in advance, and funding was not conditional upon quantifying this during the design phase.

Conclusions relevant to the Scheme

NFM has a role to play in flood risk management generally when combined with engineered methods as part of a whole-catchment approach to reducing flood risk. It may also be capable of delivering other desirable NbS outcomes.

While NFM on the Eddleston Water project has been demonstrated to reduce peak flows by 5% on a 69km^2 catchment, Musselburgh FPS would require a 50% reduction in the peak flow of the River Esk (330km^2 catchment) to avoid the need for physical defences during a present-day 0.5% AEP event . A 5% reduction would facilitate only a minimal reduction in the required flood defence heights.

The approach to implementing NFM measures taken by the Eddleston Water project may be incompatible with the approach to developing a flood protection scheme under the Flood Risk Management (Scotland) Act 2009. Voluntary agreements with landowners may introduce various legal risks. Implementing NFM measures with no quantifiable reduction in flood risk at the time of design may introduce funding and design liability risks.

Recommendations for the Scheme

On the basis of the above conclusions relevant to the Eddleston Water Project and to the Scheme, Jacobs recommends that:

- The potential for NFM measures in the River Esk catchment should still be investigated further, with a view to them contributing to a long-term managed adaptive approach in response to future increases in flood risk to Musselburgh. This would be best delivered independently of the Scheme so that the timescales associated with achieving landowner agreement and baseline monitoring do not delay the Scheme's ability to proceed with protecting Musselburgh from the present-day flood risk.
- ELC encourages and supports the formation of an independent body, like Tweed Forum, for the Esk catchment, which would be capable of engaging with landowners to broker agreements between them and ELC for the purposes of delivering NFM in the Esk catchment.
- Besides NFM, the use of NbS within the Scheme should be leveraged fully to deliver as many other positive outcomes as possible in the catchment, within the river corridor in Musselburgh, and along the Musselburgh coastline. Such outcomes could include biodiversity enhancement, fish passage improvement, increased water quality and habitat creation. This approach is consistent with the ethos of Scotland's recently published National Planning Framework 4 (NPF4), (Scottish Government, 2023).

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