Cork County Council

Midleton Flood Relief Scheme

Natural Flood Management Feasibility Report

Issue 1 | 16 February 2021

Job number 252803-56

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Abbreviations

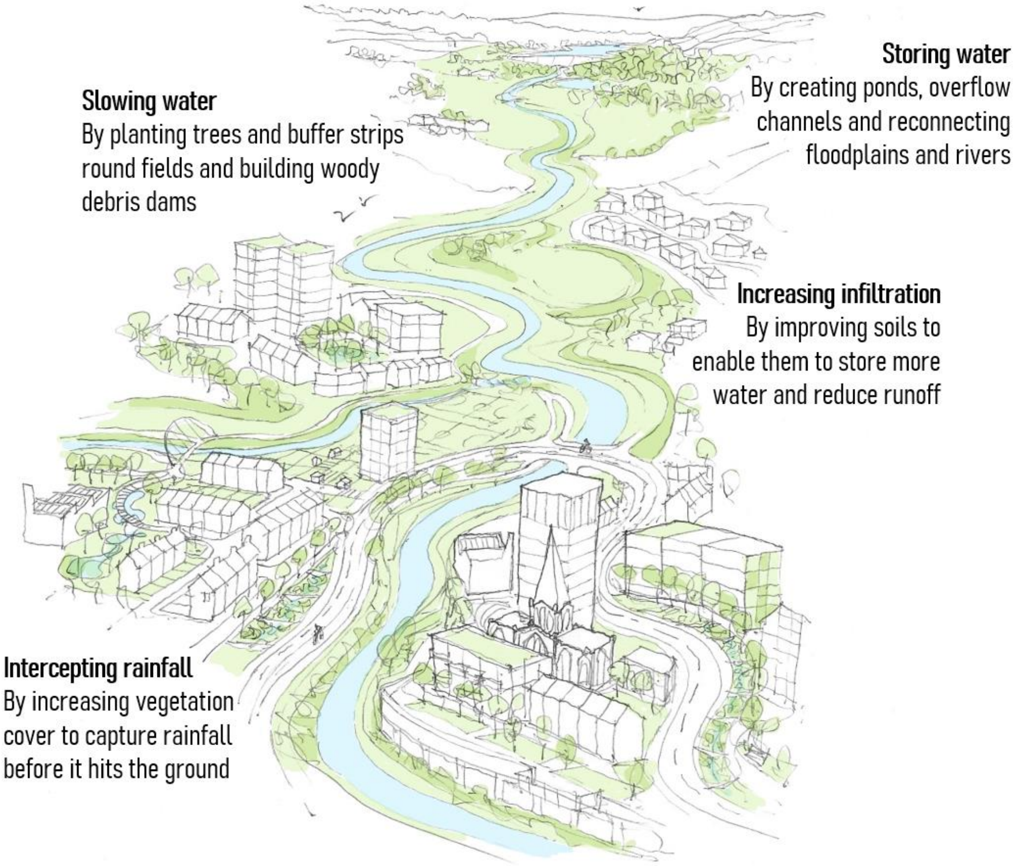
ASM – Aggregate Storage Model
BPS – Basic Payment Scheme
CFRAM - Catchment Flood Risk Assessment and Management
CSE – Catchment Systems Engineering
FRMP – Flood Risk Management Plan
FRS – Flood Relief Scheme
GIS – Geographic Information Systems
GLAS - Green, Low-carbon, Agri-environment Scheme
HEP – Hydrological Estimation Point
LiDAR – Light Detecting and Ranging
LWD – Large Woody Debris
NFM – Natural Flood Management
NWRM – Natural Water Retention Measures
OPW – Office of Public Works
RAF – Runoff Attenuation Feature

Non-Technical Summary

What is NFM?

Natural Flood Management (NFM), or Natural Water Retention Measures (NWRM) as it is often referred to, involves implementing features to restore or mimic the natural functions of rivers, floodplains and the wider catchment to reduce flood risk downstream[1].

Traditional methods of reducing flood risk often involve large concrete and metal structures in and around towns, often including walls and embankments which create a divide between communities and our natural watercourses. However, there is an increasing demand to look at the wider landscape to manage flood risk, by slowing water down before it reaches our towns and cities, and temporarily storing it elsewhere during times of flood. NFM aims to store water in the landscape, where it will not cause damage to properties or infrastructure, and slow the rate at which water runs across the landscape and into rivers. The main mechanisms of NFM are highlighted in the sketch below.



[1] Yorkshire Dales National Park Authority, Yorkshire Dales Rivers Trust and North Yorkshire County Council, with support from Natural England and the Environment Agency (2018) Natural Flood Management Measures – a practical guide for farmers.

What are the Solutions?

We have assessed seven types of NFM features and their feasibility in the Midleton catchment, based on a variety of landscape characteristics. The features we are proposing include:

Runoff Attenuation – a bund that captures and stores runoff water in fields

Large Woody Debris (LWD) – placement of wood across a river channel to act as a dam and slow water

Tree Planting – to intercept rainfall and reduce runoff by increasing infiltration and stabilise soils

Floodplain Reconnection – where rivers are constrained to their channels, joining up rivers with their floodplains to enhance storage capacity during floods

Wet Woodland – wooded areas that experience waterlogged conditions to manage flood waters, erosion and water quality

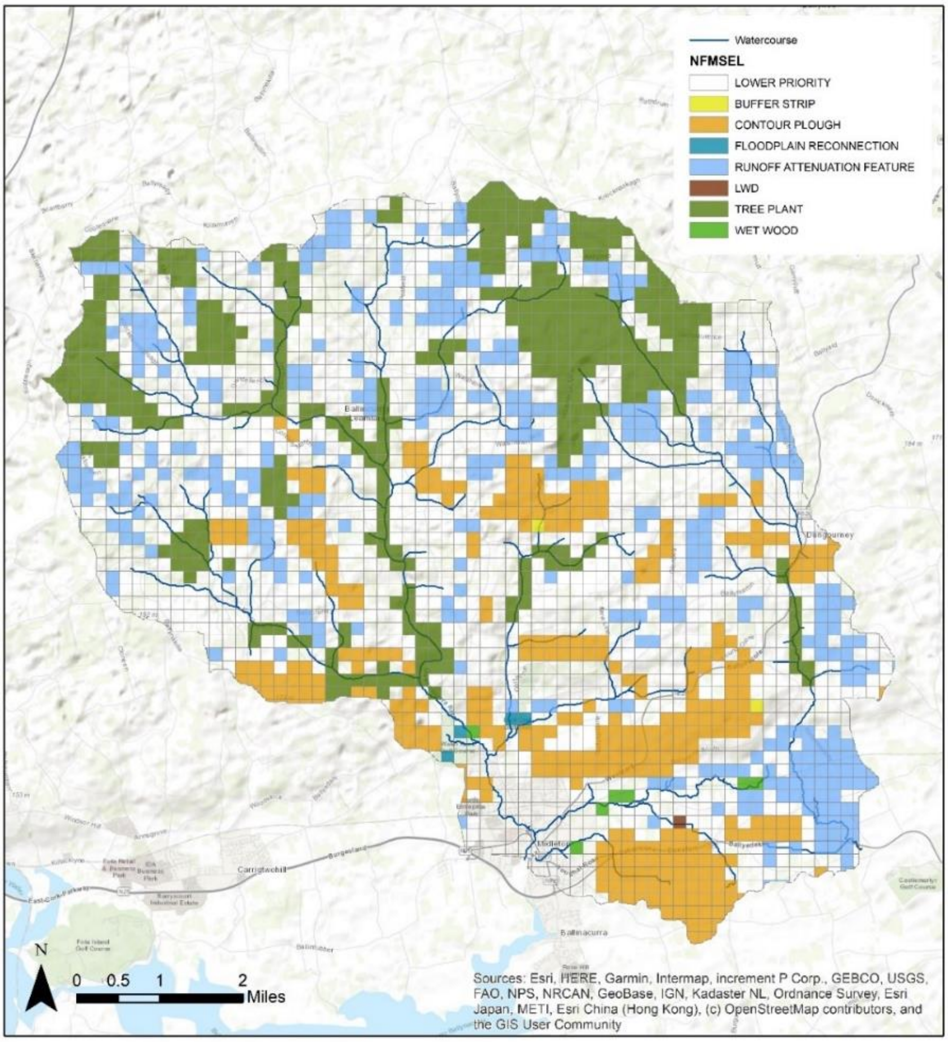
Buffer Strip – area of long grasses, trees and shrubs along field boundaries to intercept rainfall and runoff

Contour Plough – agricultural practice of ploughing along the contours of the land to prevent soil compaction and erosion and prevent runnels channelling water downstream

How could these be implemented in Midleton?

To determine if NFM is suitable in the Midleton catchment, where NFM could be implemented and what type of feature is best suited, we created a gridded analysis of the whole catchment. We considered landscape variables such as land use, steepness of slopes, watercourses and areas of high flood risk. Owing to these variables and NFM being less suited in certain areas, a proportion of the catchment was considered to be a lower priority for this analysis, as indicated in the map below.

Of the area that is suitable for NFM, Tree Planting and Runoff Attenuation features are considered to be the most suitable and are recommended for approximately 1/3 of the suitable NFM area. These proposed features are largely in the upper and middle reaches of the catchment. Contour ploughing is also recommended across the catchment, especially in the middle reaches, and is proposed across ~30% of the suitable NFM area. The remaining interventions are largely in the middle to lower catchment, comprising wet woodland, floodplain reconnection, buffer strips and Large Woody Debris.



It should be noted that the NFM features suggested in the areas mapped are not proposed over the whole coloured area, only recommended at suitable locations within those parts of the catchment.

How would NFM impact flood risk?

We undertook analysis of the hydrology of Midleton and determined that the maximum volume of water that could be stored in the catchment is 386,000m^3. Six scenarios were developed based on a set of assumptions to test the impact of adopting different approaches and NFM types and their storage volumes. These scenarios included analysing the implementation of numerous traditional NFM features capable of storing approximately 500m^3 of water each, and a series of fewer, larger NFM features capable of storing up to 10,000m^3 each.

Implementation of these NFM opportunities in the catchment could result in an 8% decrease in peak flow at Midleton using traditional NFM features, or a 10% decrease in peak flow using fewer, larger NFM features.

What could this cost?

A conservative analysis of the cost of delivering a storage-based NFM scheme by implementing traditional NFM in the prioritised catchment areas would be in the region of €6.8m to €12.3m total project costs and could achieve a reduction of around 6% in peak flow.

If the fewer, larger NFM features approach was adopted, a peak flow reduction in the order of 10% could be achieved for a cost of €10.5m to €15.5m total project costs. Over a 30-year design life, it is thought that a conservative estimate of the overall cost of the storage-based NFM scheme could be approximately €900k, this is included in the total project costs.

Is NFM a viable option for Midleton?

Reduction of peak flow by 6-10% through NFM could lead to a minor reduction in the extent of structural flood defences within the Owenacurra fluvially dominated area of Scheme Area. However, to put the scale of this potential reduction into context, it should be noted that the implementation of Option 1C, the storage and direct defences option presented at PPD2, would result in approximately 30% reduction in peak flow.

NFM measures would not contribute to any reduction in flood defence requirements on the Dungourney as the area requiring defences is also subject to tidal flooding.

Therefore, it is concluded that the reduction in structural flood defence requirements along the Owenacurra would be minimal with the implementation of an NFM approach. In the context of the scale of intervention, the costs, the landowner engagement required and the logistics of construction and maintenance of NFM in this area, it is evident that a Natural Flood Management solution is not technically viable as an option or even in combination with other measures. However, NFM could be considered as a future measure within the Climate Change Adaptability Plan subject to further investigation.

Executive Summary

This study seeks to provide an evidence base to demonstrate the extent to which Natural Flood Management (NFM) measures could reduce and attenuate peak flows in the Owenacurra and Dungourney catchments and provide flood risk mitigation in Midleton, located downstream.

The requirement for this study was prompted by the latest Office of Public Works (OPW) flood relief scheme project briefs which include for a comprehensive assessment of Natural Water Retention Measures. Furthermore, there were numerous references to the use of NFM at a Public Participation Day relating to the wider Flood Relief Scheme (FRS).

Therefore, it was agreed that a study is required to provide clarity on the potential and feasibility for NFM for the Midleton FRS. The scope of this study largely considers what is required within the Ballinasloe FRS brief, which is understood as the latest OPW flood relief scheme brief requirements.

The Owenacurra and Dungourney catchments have been analysed using a variety of geospatial analysis using ArcGIS, a statistical breakdown of NFM intervention suitability and hydrological analysis of the study area, broken-down into nine hydrological study units, using an Arup-developed Aggregate Storage Model (ASM).

Geospatial analysis of the catchment enabled an understanding of the local characteristics and suitability for NFM, including land cover and slope. Seven NFM interventions (buffer strips, large woody debris, contour ploughing, runoff attenuation features, floodplain reconnection, tree planting and wet woodland as defined below in the report) were then scored based on the local catchment characteristics, alongside a variety of other considerations such as approximate cost of implementation and potential wider environmental benefits. The NFM interventions include:

- Runoff Attenuation – a bund that captures and stores runoff water in fields;
- Large Woody Debris (LWD) – placement of wood across a river channel to act as a dam and slow water;
- Tree Planting – to intercept rainfall and reduce runoff by increasing infiltration and stabilise soils;
- Floodplain Reconnection – where rivers are constrained to their channels, joining up rivers with their floodplains to enhance storage capacity during floods;
- Wet Woodland – wooded areas that experience waterlogged conditions to manage flood waters, erosion and water quality;
- Buffer Strip – area of long grasses, trees and shrubs along field boundaries to intercept rainfall and runoff; and
- Contour Plough – agricultural practice of ploughing along the contours of the land to prevent soil compaction and erosion and prevent runnels channelling water downstream.

The scored NFM interventions enabled the most suitable intervention to be identified across each 250m x 250m (6.25ha) grid square within the catchment. This indicated that Tree Planting was the most suitable NFM intervention across ~47.6% of the catchment, followed by Runoff Attenuation across ~38% of the catchment area. Contour ploughing was indicated to be the most suitable NFM intervention across ~13.9% with just a few grid cells suggested as suitable locations for buffer strips, floodplain reconnection, large woody debris or wet woodland. This indicates that these NFM features may not be the most suitable for the Midleton catchment. As such, a minimum score was then set, to prioritise NFM in the most suitable locations throughout the catchment. This resulted in approximately 54% of the catchment being considered as lower priority for NFM interventions, and the highest scoring NFM feature for the remainder of the catchment area was reported.

Tree Planting and Runoff Attenuation features scored highly across the catchment, accounting for 34.56% and 34.06%, respectively, of the area prioritised for NFM. The spatial distribution of these interventions are largely in the upper and middle reaches of the catchment. Contour ploughing also scored well across the catchment, especially in the middle reaches, and are proposed across 30.22% of the prioritised catchment area. The remaining interventions are largely in the middle to lower catchment, comprising wet woodland (0.58%), floodplain reconnection (0.33%), buffer strips (0.17%) and Large Woody Debris (0.08%).

A hydrological analysis of NFM storage potential was conducted alongside the opportunity mapping using the Aggregate Storage Model (ASM). The analysis identified that a maximum volume of 386,000m^3 can be stored throughout the 154.46km^2 catchment. Six scenarios were developed based on a set of assumptions to test the impact of adopting different approaches and storage volumes. Three scenarios (A1, A2 and A3) examine more traditional NFM storage techniques using between 450 and 800 storage features each containing an average volume of approximately 500m^3. The other three scenarios (B1, B2, and B3) use a Catchment Systems Engineering (CSE) NFM approach, which involves the use of fewer storage ponds of individually larger volumes (<10,000m^3).

The maximum achievable reduction in peak flow (the maximum flow rate at Midleton during a 1 in 100 year storm event) at Midleton is 7.9% (scenario A1) using traditional NFM storage techniques and 9.4% (scenario B1) using the CSE approach.

Targeting NFM intervention measures in three headwater sub-catchments (Owenacurra 1, 2 and 3) rather than across all nine sub-catchments produces the most effective peak flow reduction at Midleton. Results between the two different approaches are comparable, at 6.1% for traditional NFM (scenario A3) and 6.9% for the CSE approach (scenario B3).

The results presented in this study are highly conservative and are considered to underestimate the potential benefits of NFM. This is consistent with the philosophy of the hydrology report but may underestimate the potential benefits of NFM in terms of peak flow reduction at Midleton.

Midleton catchment covers an area of 154km^2 ; there are few examples where NFM is being used to reduce flood risk in catchments in the order of 150km^2 as this is a new area of NFM application. However, it is important to note that NFM has been demonstrated to be effective at scales in the order of 10 - 40km^2 (e.g. Belford, Northumberland and Coatham Woods, Stockton-On-Tees). A CSE scheme at Coatham Woods reduces the 1 in 75 year flood event flows at the outfall of a 15km^2 catchment at Stockton-on-Tees by 10%. These types of headwater catchment exists everywhere across the British Isles. Therefore, the assumptions made in this study are applicable because the Midleton catchment is comprised of many smaller headwater catchments like Belford and Coatham Woods, in which NFM is effective.

When considering both storage and non-storage based NFM measures, by applying a traditional NFM approach a reduction of around 6% could be achieved for €6.8m to €12.3m project total cost.

If a CSE approach was adopted, a peak flow reduction in the order of 10% could be achieved for a project total cost of €10.5m to €15.5m. This excludes non-storage based NFM measures.

All costs are based on assumptions that conventional contractors would carry out the works and does not include consideration of optimism bias, maintenance or mobilisation costs. Over a 30-year life cycle, it is estimated that a conservative estimate of the overall maintenance cost of the storage-based NFM scheme could be approximately €900k, which is included in the cost estimates.

Reduction of peak flow by 6-10% through NFM could lead to a minor reduction in the extent of structural flood defences within the Owenacurra fluvially dominated area of Scheme Area. However, to put the scale of this potential reduction into context, it should be noted that the implementation of Option 1C, the storage and direct defences option presented at PPD2, would result in approximately 30% reduction in peak flow.

Therefore, it is concluded that the reduction in structural flood defence requirements along the Owenacurra would be minimal and in the context of the scale of intervention, the costs, landowner engagement required and the logistics of construction and maintenance of NFM in this area, it is evident that a Natural Flood Management solution is not technically viable as an option or even in combination with other measures. However, NFM could be considered as a future measure within the Climate Change Adaptability Plan subject to further investigation.

1 Introduction

This study seeks to provide an evidence base to demonstrate the extent to which Natural Flood Management (NFM) measures could reduce and attenuate peak flows in the Owenacurra and Dungourney catchments and provide flood risk mitigation in Midleton, located downstream.

Increasingly, NFM, or Natural Water Retention Measures (NWRM), is seen as a flood risk management solution that provides sustainable, iterative and multi-functional benefits in addition to the primary flooding function.

NFM is defined as the alteration, restoration or use of landscape features to reduce flood risk[2]. It is widely promoted as a suitable non-structural measure for mitigating flows during flood events[3,4]. Identified interventions would enable the slowing of flow of water through the catchments, mitigating the existing risk of downstream flooding at Midleton. Simultaneously, interventions chosen would aim to maximise the potential of ecosystem services benefits (e.g. amenity and health access, biodiversity, and lower embodied carbon) associated with NFM techniques for the natural environment and the community they serve.

1.1 Study Objectives

The latest Office of Public Works (OPW) flood relief scheme project briefs include for a comprehensive assessment of Natural Water Retention Measures (NWRM), including production of Potential for NWRM Maps and a NWRM Feasibility Assessment to assess the feasibility of implementing specific types of NWRM, to provide some degree of flood risk reduction within the Study Area.

Furthermore, following a number of submissions specifically referencing NFM received as part of the recent Public Participation Day, it has been agreed that a study is required to provide clarity on the potential and feasibility for NFM for the Midleton FRS. The scope of this study largely considers what is required within the Ballinasloe FRS brief, which is understood as the latest OPW flood relief scheme brief requirements.

1.2 Context

Man-made catchment influences such as agriculture, urbanisation and reservoir impoundments have altered natural hydrology of catchment systems. There is anecdotal evidence that these artificial influences have led to increased flood peaks and higher rates of sediment delivery to catchment outlets. It is thought that agricultural intensification may cause higher flood peaks in streams and rivers due to its impact on runoff processes.

[2] POST. (2011). Natural Flood Management POSTNOTE 396. London, England: Parliamentary Offices of Science and Technology.
[3] SEPA. (2016). Natural flood management handbook. Edinburgh: Scottish Environment Protection Agency.
[4] European Commission. (2016). Natural Water Retention Measures website [Online].

For example, degradation of soil structure can lead to reduction in infiltration rates and available storage capacities, increasing rapid runoff in the form of overland flow[5,6]. Although flood hazard is greater in lower lying regions (i.e. areas where population is usually higher), the management of headwaters, with their generally higher precipitation rates and flashier response, is of particular interest for flood runoff generation[7].

NFM is the alteration, restoration or use of landscape features to reduce flood risk[2]. There are arguments that support the restoration of catchments through 'Rewilding', allowing natural processes and native species to reclaim their position in large areas of land. Traditional NFM can take a more 'engineered' approach to deliver many small landscape interventions that intercept and attenuate hydrological flow pathways to emulate natural processes and provide multiple benefits, including flood management and improving water quality. Put simply, the design philosophy is to create features that 'slow, store and filter' runoff and peak flow in the landscape[8]. Figure 1 shows an idealised storm hydrograph, which has had its shape altered through attenuation from NFM.

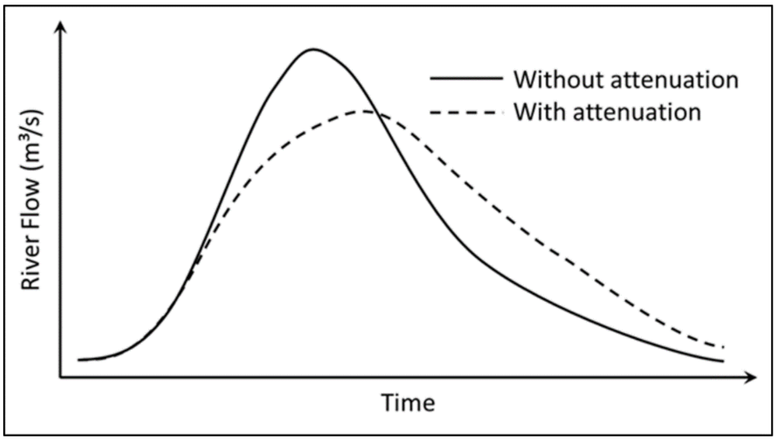


Figure 1: Attenuating flow in a hydrograph

NFM has limitations that should be understood by catchment stakeholders. Choosing locations for features, developing land-owner engagement and providing maintenance of numerous assets is not always straightforward. As a result, NFM should be considered as a wider catchment-based approach to work alongside traditional forms of flood defence.

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[5] Heathwaite, A. L., Burt, T. P., & Trudgill, S. T. (1990). Land-use controls on sediment production in a lowland catchment, south-west England. In J. Boardman, I. D. Foster, & J. A. Dearing, *Soil Erosion on Agricultural Land.* John Wiley and Sons Ltd.
[6] Bronstert, A., Niehoff, D., & Burger, G. (2002). Effects of climate and land-use change on storm runoff generation: present knowledge and modelling capabilities. *Hydrological Processes, 16*, 509-529.
[7] Wheater, H., Reynolds, B., Mcintyre, N., Marshall, M., Jackson, B., Frogbrook, Z., Soloway, I., Francis, O. & Chell, J. (2008). *Impacts of upland land management on flood risk: Multi-scale modelling methodology and results from the pontbren experiment.* FRMRC Research Report UR 16.
[8] Nicholson, A. R., Wilkinson, M. E., O'Donnell, G. M. & Quinn, P. F., 2012. Runoff Attenuation Features: A sustainable flood mitigation strategy in the Belford Catchment, UK. Area, 44(4), pp. 463-469.

NFM has the potential to increase resilience of other proposed measuresby attenuating flood flow, capturing sediment before it enters the watercourse[9], creating habitat and increasing climate change resilience. Examples include better land use management and catchment-wide water storage (for example, the runoff attenuation approach in Belford, Northumberland[10]).

[9] Barber, N. J., & Quinn, P. F. (2012). Mitigating diffuse water pollution from agriculture using soft-engineered runoff attenuation features. *Area*, *44*(4), 454-462.
[10] Quinn, P. et al., 2013. Potential use of Runoff Attenuation Features in small rural catchments for flood mitigation: Evidence from Belford, Powburn and Hepscott, s.l.: Joint Newcastle University, Royal Haskoning and Environment Agency Report.

2 Methodology

2.1 Overview

This study assesses the potential impact NFM interventions could have on peak flow for the Owenacurra and Dungourney rivers and the resulting effect on flood risk at Midleton. The study catchment comprises approximately 154km^2 and is shown in Figure 2.

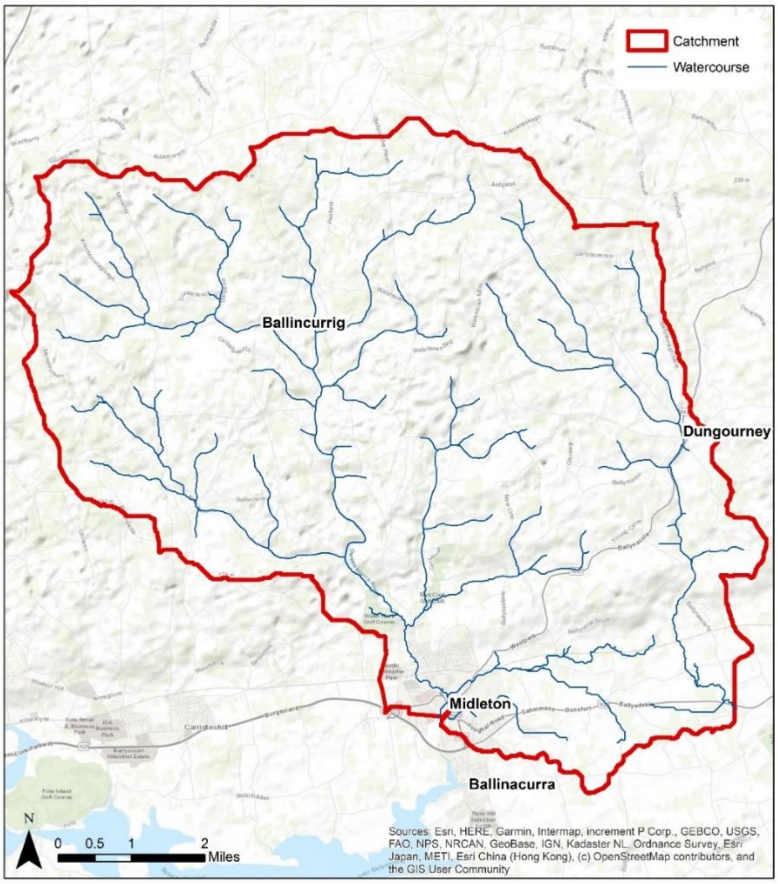


Figure 2: The study catchment of the Owenacurra and Dungourney Rivers

In order to assess the hydrological impact of certain tributaries and stretches of the Owenacurra and Dungourney rivers, the overall study catchment was divided up into nine sub-catchments representing hydrological units, shown in Figure 3.

Figure 3: The nine sub-catchments within the study catchment, representing the different hydrological units

As part of the Midleton FRS hydrology study[11], Hydrological Estimation Points (HEPs) were generated throughout the catchment, including at the outlet of each sub-catchment shown in Figure 3, indicating the flow upstream of each point. The study generated regularly-shaped design hydrographs representing flow within each hydrological unit. This data has been analysed using an Aggregate Storage Model (ASM), alongside the geospatial analysis using ArcGIS and an Arup developed NFM feasibility tool, to map NFM opportunities throughout the Owenacurra and Dungourney catchment. The Waterrock and Ballinacurra rivers were excluded from the analysis due to a lack of available data.

2.2 GIS Analysis

ArcGIS software (version 10.7.1) has been used to spatially analyse the catchments in the study area in order to undertake coarse opportunity mapping.

[11] Cork County Council, River Owenacurra & River Dungourney (Midleton) Flood Relief Scheme Hydrology Report, 21 February 2019

This GIS analysis is based on a variety of data sources and analytical tools, described in this section.

2.2.1 Data Sources

Data from public and downloadable sources that have been used for analysis, include:

- Topographic data, called LiDAR, at 5m resolution;
- Background Mapping;
- Corine Land Cover Maps;
- 1 in 100-year Flood Extent from Preliminary Flood Risk Assessment National Maps (www.floodinfo.ie);
- Hydrological Flow Data (Arup).

2.2.2 Topographic and Flow Analysis

A GIS analysis of the topographic data (LiDAR) identified areas with the potential for surface runoff generation using a series of analytic 'Hydro-Tools' within ArcGIS. This analysed the topographic data to establish the direction of flow and likely areas of flow accumulation within the catchments.

The Strahler (1957) stream order method was utilised to establish the relative size of streams within the river network of the study area. A threshold was set for the first order streams, such that 0.5km (50ha) of contributing drainage area is required before the streams are drawn.

Additional thresholds were set to determine primary and secondary runoff routes in the catchment. The threshold was set to consider runoff between 5ha and 50ha (0.5km^2) of contributing drainage area for primary runoff routes. These are considered to be active in low to medium magnitude storm events and are therefore more established runoff routes.

A final threshold was set to assess secondary runoff routes between 1ha and 5ha of contributing drainage area for secondary runoff routes. These may take longer to generate during rainfall events, but intercepting water from these ephemeral flow paths is more likely to target peak flow in high magnitude rainfall events. The stream order and runoff routes across the study catchment, are shown in Figure 4 below.

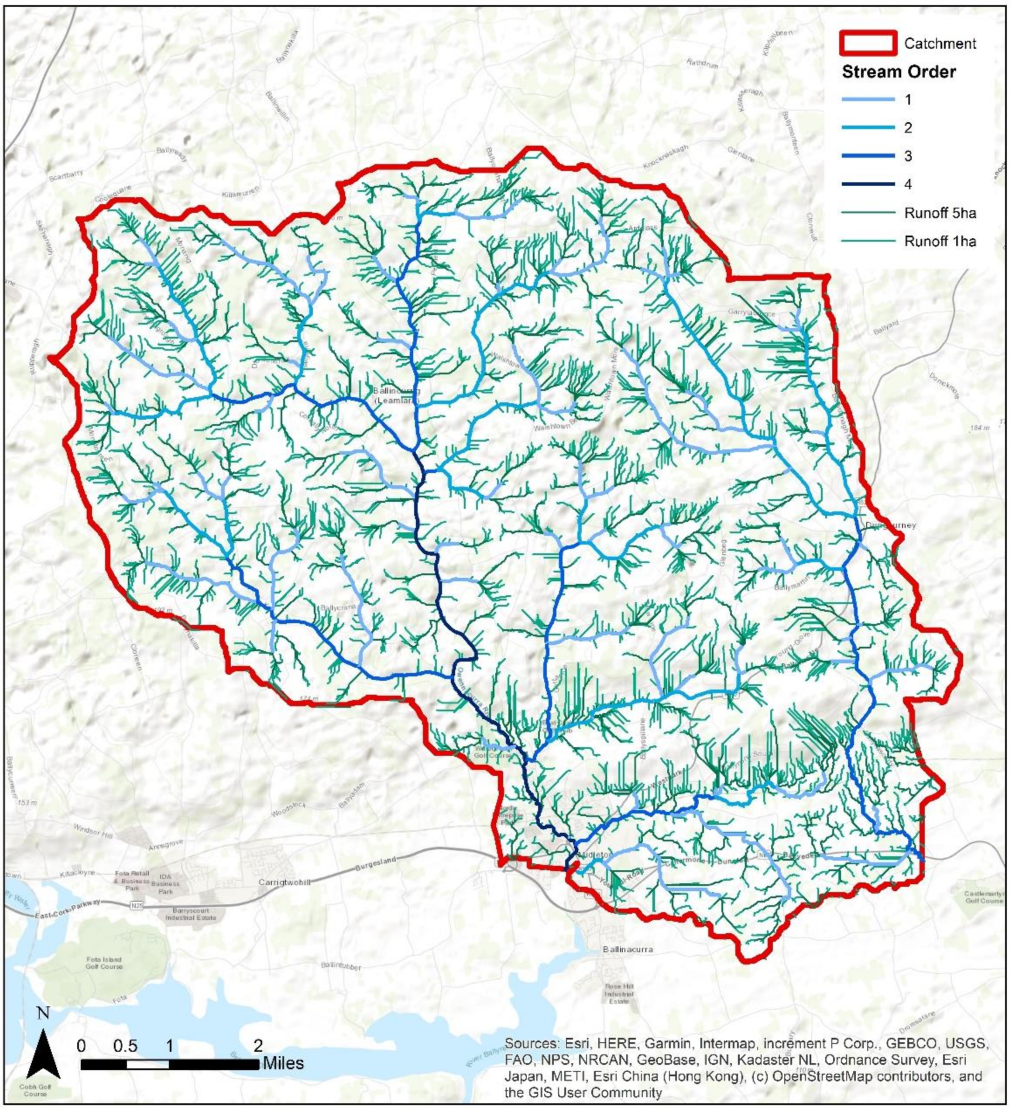


Figure 4: The Stream Order for the Owenacurra and Dungourney catchment (using the Strahler method) and the runoff pathways

The LiDAR data was used to generate a layer representing slope across the catchment. Slope is an important component to consider as it not only dictates where runoff will occur, but where higher levels of storage can be positioned to capture that runoff. Figure 5 shows how the angle of slope can affect the storage potential of an NFM feature of a certain size.

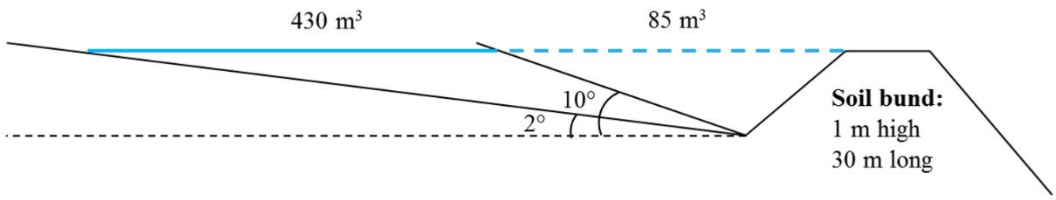


Figure 5: Example cross section of an NFM intervention and its potential storage volume when located on slopes of different angles

The slope layer was generated at a 50m resolution and then categorised into steepness between 0°-2°, 2°-4°, 4°-6°, 6°-8°and >8°. Slope angles of less than 8° are considered suitable and preferable for NFM interventions and water storage. Figure 6 indicates the localised areas of steep slopes in the upper catchment and the relatively flat lower catchment in the south of the study area.

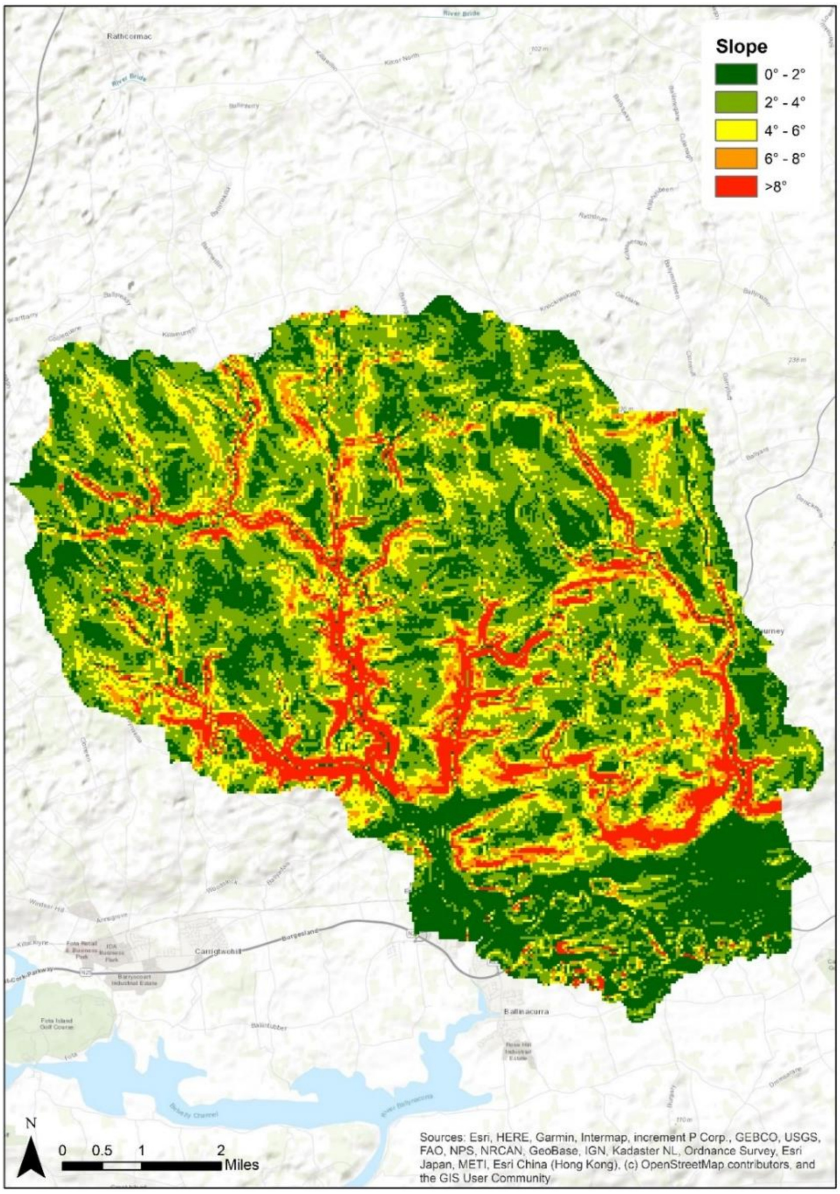


Figure 6: The angle of slope throughout the catchment at a 50m by 50m scale

The purpose of mapping these runoff routes and slope is to use them, in combination with other mapping layers, to determine feasible locations for NFM. The output from the ArcGIS analysis was combined with background mapping, fluvial flood risk layers, land use data, and satellite imagery to determine feasible locations for NFM interventions.

2.2.3 Estimating NFM Potential

In order to assess the character of the sub-catchments, a 'Fishnet' grid system has been applied to the entire catchment. The grid squares are 250m x 250m, and there are a total of 2,603 grid squares across the whole catchment (though many of the perimeter grid squares only contain a small area of catchment). The presence of a variety of catchment variables within each grid square was then determined.

This includes the percentage area of different land cover defined by the Corine Land Cover dataset (generated in 2018), the percentage area of each slope category and area within the 1 in 100-year flood extent and finally, the total length of runoff pathways within each grid square. An example of the fishnet grid overlaying the Corine Land Cover dataset is provided in Figure 7.

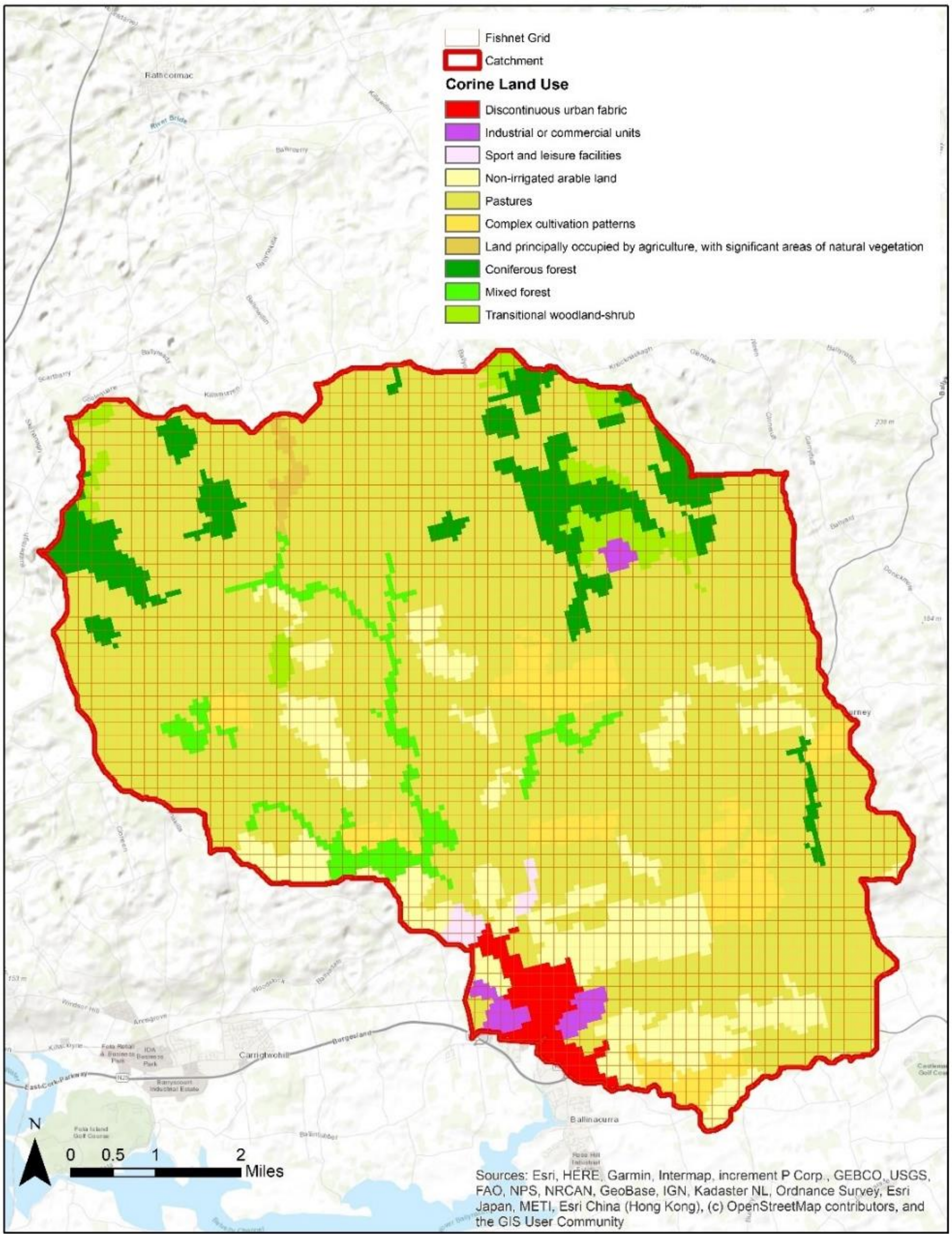


Figure 7: The Corine Land Cover classification overlain by the fishnet grid

2.2.4 NFM Feasibility Analysis

These geospatial analyses were then exported into an Arup developed NFM methodology to assess feasibility of a range of NFM types.

The method utilises a series of look ups which determine the feasibility of seven different NFM intervention types, scored between one and five based on their suitability (five being most suitable) for each individual factor as shown in Appendix A. Note, these scores are estimates, based on in-depth technical understanding and previous project outcomes and can be amended where appropriate during any more detailed mapping analysis. The following NFM interventions, based on their primary purpose, were analysed:

Runoff reduction:

- Runoff Attenuation – a man-made structure that intercepts and attenuates a hydrological flow (runoff) pathway (e.g. an earth bund or ‘leaky barrier’);
- Large Woody Debris (LWD) – placement of wood across/within the channel to act as a dam and slow the flow. The use of full-span large woody debris would be limited to catchment areas of 3km^2 or less, so catchment headwaters. Beyond this scale alternative designs of LWD (partial-span) would be considered. All LWD should allow for fish passage to be maintained, by allowing low flow beneath the intervention; and
- Tree Planting – planting trees can intercept rainfall, reduce runoff by increasing infiltration and stabilise soils. Assumptions relating to tree planting and existing land cover are discussed in Section 4.1.1.

Floodplain Storage:

- Floodplain Reconnection – establishing a pathway between a watercourse and its natural floodplain, especially during high flows, where flood waters were previously constrained to the channel; and
- Wet Woodland – wooded areas that experience waterlogged conditions for at least part of the year to manage flood waters, erosion and water quality

Sediment and nutrient management:

- Buffer Strip – area of long grasses, trees and shrubs along field boundaries or across fields; and
- Contour Plough – agricultural practice of ploughing along the contours of the land (as part of normal cultivation practices) to prevent soil compaction and erosion and prevent runnels channelling water downstream.

An example of these seven NFM intervention types are provided in Table 1.

Table 1: Examples of the NFM interventions analysed in this study

Intervention Type	**Example**
Runoff attenuation (©Newcastle University)	 
Floodplain Reconnection (©National Trust)	
Large Woody Debris (©Newcastle University)	 
Tree Planting (© Environment Agency)	

Intervention Type	Example
Wet Woodland (© London Wildlife Trust)	
Contour Plough (© USDA-NRCS)	
Buffer Strip (©The James Hutton Institute)	

The criteria on which the NFM interventions were scored were assessed in an evaluation matrix to weight modelling results, spatial factors, costs, maintenance responsibilities and numerous ecosystem services. The full list of factors included in the matrix is explained in Table 2 below. Considering other factors in the ranking of opportunities has the potential to reduce the impact of modelling uncertainty. It also allows for the inclusion of other important factors into the analysis.

The weightings were designed to cover the most influential factors of successful NFM projects.

The purpose of the criteria is to identify the highest ranking NFM opportunities with, theoretically, the greatest potential to yield success in an NFM project and identify relevant funding sources based on the biggest benefits likely to be achieved. The default weightings are intended to cover schemes with a good balance of criteria supporting NFM. Should a scheme's potential for receiving funding highly depend on the reduction in flood risk, more emphasis can be put on the modelling weightings.

Table 2: NFM evaluation criteria and the weightings applied in the evaluation matrix

Evaluation Criteria	Sub-criteria	Sub-criteria weighting
Hydrology	Slope	10.00%
	% Floodplain	5.00%
	Runoff route length	5.00%
Funding & Future	Cost	3.33%
	Maintenance	3.33%
	Life Expectancy	3.33%
Land Use	Land Cover	35.00%
Ecosystem Services	Flood (Fluvial)	3.50%
	Flood (Surface water or Groundwater)	3.50%
	Air Quality	3.50%
	Health Access	3.50%
	Low Flows	3.50%
	Climate regulation	3.50%
	Habitat	3.50%
	Water Quality	3.50%
	Cultural Activity	3.50%
	Aesthetic Quality	3.50%

A variety of weighting controls were trialled for the catchments but, ultimately, the highest weightings (35%) were attributed to land use and ecosystem services given their strong influence on the possibility and type of NFM intervention and their overall impact on the environment.

Ecosystem services represent the direct and indirect contributions of ecosystems to our quality of life and well-being. This includes the provision of services such as food and water, regulating services such as climate regulation and water purification, habitat services and cultural services such as recreation and aesthetic value. The following ecosystem services were incorporated into the analysis to meet objectives other than flood risk management:

- Flood risk management (fluvial) (positive impact on fluvial flood risk reduction);
- Flood risk management (surface water or groundwater) (positive impact of surface or groundwater flood risk reduction);
- Air Quality (interventions leading to improvements in air quality);

- Health Access (creation of greater amenity for the public, thus generating improvements in terms of physical and mental health of local population);
- Low Flows (regulation of low flows through capture and infiltration);
- Climate Regulation (contribution to regulation of climate change);
- Habitat (provision of amenity to locally important species);
- Water Quality (potential to capture and/or filter polluted flow from farmland or other sources);
- Cultural Activities (potential to provide direct recreational benefit to the public such as facilitating angling by improving fish habitat); and
- Aesthetic Quality (interventions providing improvements to the local landscape).

Financial considerations (including cost, maintenance and life expectancy), localised flooding characteristics (floodplain extent and length of runoff routes) and angle of slope (and therefore storage potential) were assigned an equal weighting of 10% each. Note, weighting controls given to each criterion are flexible and can be adapted depending on the aspirations of the study. The scoring assigned to each NFM intervention for each variable is provided in Appendix A.

Using scores awarded to the variables, the weighting of each criterion and percentage / presence of each variable, the most suitable NFM intervention was selected for each grid cell. Selected interventions could then be visualised using ArcGIS cartography.

2.3 Hydrological Analysis

In parallel with the geospatial opportunity mapping outlined above, a hydrological analysis was undertaken to quantify the impact of introducing NFM storage features within the nine sub-catchments. The approach uses the hydrograph data from the HEPs and the ASM to model the impact of adding storage within sub-catchments on the downstream peak flows at Midleton for the 1 in 100-year design event.

2.3.1 Calibration of Flow Data

From the HEPs, design hydrographs were produced for each of the sub-catchments Owenacurra 1 to 9. To determine accurate peak flows based on a simulated real event, results from a hydraulic model were extracted downstream of the confluence between the Owenacurra and the Dungourney rivers, immediately downstream of the study area.

The hydraulic model peak flows are generally considered to be more accurate than the HEP points, therefore the design hydrographs were then multiplied by a scaling factor of 1.1406 to produce a conservative (worst-case) overall design storm hydrograph, consistent with the conservative approach undertaken in the Midleton Hydrology Report[11]. The scaling factor was derived by dividing the hydraulic model peak flow by the peak flow as derived from the HEP points.

The peak flow at the downstream extent of the study area was therefore 98.8m^3/s for the 1 in 100-year design storm.

2.3.2 Climate change

NFM measures have adaptive capacity to mitigate climate change by increasing a catchment's resilience. NFM measures can reduce peak flows and increase the time to peak creating a buffer to help mitigate the adverse impacts of climate change.

The modelled hydrological data provided did not include provision for climate change. However, the conservative approach undertaken in generating the hydrological data is considered to account for a degree of climate change. The scaling factor of 1.14 can be considered as accounting for a 14% increase in peak flow caused by climate change.

2.3.3 High level appraisal of available catchment storage

Further to the flow data through the catchment, it is also important to estimate the storage availability within the Midleton catchment. For an initial high level assessment, based on the scientific literature[12] and Arup's project experience working on other NFM schemes, it is reasonable to assume that 2,000m^3 to 4,000m^3 of storage can be achieved per km^2 of catchment area in a catchment such as Midleton[12]. The land-use mapping undertaken using GIS provides results which are consistent with this assumption. In keeping with the conservative approach adopted for this study, a volume of 2,500m^3 of storage per km^2 will be assumed for the purposes of initial assessment.

Table 3 shows the areas of each sub-catchment and the maximum storage potential for NFM, assuming a volume of 2,500m^3 is available per square kilometre. Overall, a total of 386,162m^3 of storage is available in the Midleton catchment.

Table 3: Sub-catchments shown by area and maximum available storage volume

Sub-catchment	Area (km^2)	Maximum Available Storage Volume for NFM feature (m^3)
Owenacurra 1	19.19	47,970
Owenacurra 2	54.53	136,327
Owenacurra 3	21.30	53,251
Owenacurra 4	12.72	31,798
Owenacurra 5	8.25	20,622
Owenacurra 6	14.35	35,862.84
Owenacurra 7	7.22	18,046.42

[12] Nicholson, A. R., Wilkinson, M. E., O'Donnell, G. M. & Quinn, P. F., 2012. Runoff Attenuation Features: A sustainable flood mitigation strategy in the Belford Catchment, UK. Area, 44(4), pp. 463-469.

Sub-catchment	**Area (km^2)**	**Maximum Available Storage Volume for NFM feature (m^3)**
Owenacurra 8	10.19	25,475
Owenacurra 9	6.72	16,810.16
Whole Catchment (upstream of Midleton)	154.46	386,162.42

2.3.4 Two Approaches to NFM Storage Interventions

Available storage volume within a catchment can be utilised using two different design philosophies, both of which follow the same overarching NFM principles of slowing the flow and storing and filtering stormwater in the catchment to reduce flood risk downstream. These have been adopted to model six different NFM scenarios, as described below, within the catchment.

Traditional NFM Storage Approach

Typically, stream order of a river catchment (Section 2.2.2) provides a useful metric to determine the scale of appropriate NFM intervention. 1st and 2nd order channels are present throughout catchments and are often referred to as 'headwaters.' Traditional NFM is generally applicable throughout these parts of the stream network.

The traditional NFM approach to increasing storage capacity delivers many small landscape interventions that intercept and attenuate hydrological flow pathways to emulate natural processes and provide multiple benefits, including flood management and improving water quality. This approach uses Runoff Attenuation Features (RAFs) to slow, store and filter runoff and peak flow in the landscape. The average storage volume of these features is assumed to be approximately 500m3.

Catchment Systems Engineering (CSE) Storage Approach

Larger structures designed to store more water are appropriate for 3rd order streams (and greater). These can be engineered structures (designed to look natural) that target flow capture within a particular part of the hydrograph, designed to attenuate the overall downstream flow peak.

This scenario follows the same principles of traditional storage-based NFM outlined above but offers a more targeted engineered approach. Fewer large ponds are used to slow, store and filter. These ponds are designed holistically to enrich the landscape in which they are built, offering other ecosystem services (e.g. amenity and health access, biodiversity, and lower embodied carbon) in addition to flood alleviation benefits.

In the Lustrum Beck catchment near Stockton, NE England, these features will be used to raise the standard of protection from 1:75 to 1:100 year by temporarily storing floodwater throughout the catchment without exceeding impoundment restrictions of the Reservoir Act (10,000m^3).

The scheme is the first of its kind in the UK to receive Flood Defence Grant in Aid funding for NFM features due to the potential altered level of risk and the provision of water dependent habitat areas. Construction of the scheme is due to be completed in August 2020. Figure 8 (top) shows a sketch of how the ponds are designed to operate, and Figure 8 (bottom) shows stone pitching at an inlet and outlet to two of the ponds.

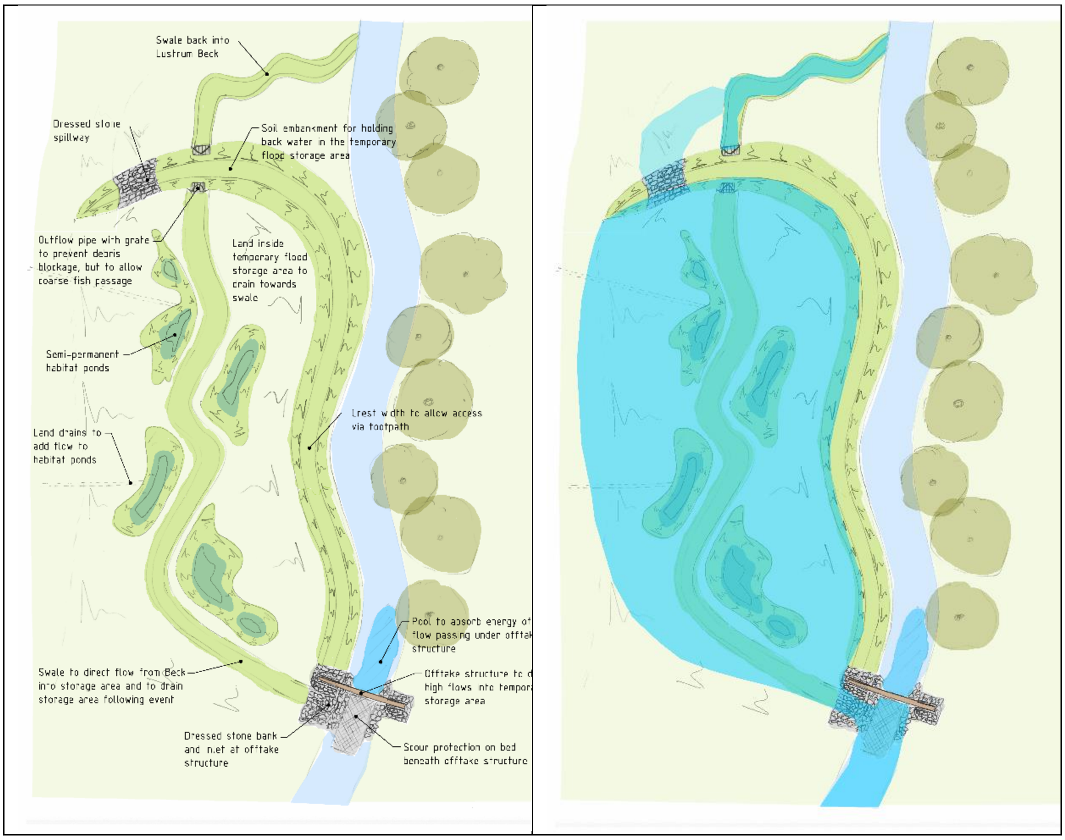


Figure 8: CSE approach at Coatham Wood, Stockton-On-Tees, indicating the pond design (top) and photo during construction in July 2020 (bottom)

2.3.5 Developing NFM Scenarios for Midleton

The six NFM scenarios considered for a design storm of 100 years, are shown in Table 4. The six scenarios can be split between the two concepts discussed above, Traditional (scenarios A1, A2 and A3) and CSE (scenarios B1, B2 and B3), and cover a range of NFM storage volume potentials. These six scenarios were then modelled using the ASM.

Table 4: Description of six storage scenarios modelled using the ASM

Scenario:	Type of Approach	Description
A1	Traditional NFM Approach	**Maximum achievable storage volume** of **~386,000m^3** distributed throughout **all nine sub-catchments across >600 field-scale NFM interventions**, each comprising an average of **500m^3**.
B1	Catchment Systems Engineering (CSE) approach, sometimes described as “NFM+”.	**Maximum achievable storage volume** of **~386,000m^3,** distributed throughout **all nine sub-catchments** via **43 larger NFM interventions**, each with a maximum volume of **10,000m^3.**
A2	Constrained Traditional NFM Approach	As Scenario A1 but **with 66% of max. volume (~257,000m^3)** due to constraints including: landowner access, environmental, geotechnical, ecological.

Scenario:	Type of Approach	Description
B2	Constrained Catchment Systems Engineering (CSE) approach, sometimes described as "NFM+".	As Scenario B1 but with **66% of max. volume (~257,000m^3)** due to constraints including: landowner access, environmental, geotechnical, ecological.
A3	Targeted Traditional NFM Approach	Same assumptions as Scenario A1 (many small NFM interventions with **reduced overall storage (<50% of Max.) targeting the specific sub-catchments (Owen 1,2 & 3)** with greatest potential for downstream flow reduction.
B3	Targeted Catchment Systems Engineering (CSE) approach, sometimes described as "NFM+".	Same assumptions as Scenario B1 (few large NFM interventions) with **reduced overall storage (<50% of Max.) targeting the specific sub-catchments (Owen 1,2 & 3)** with greatest potential for downstream flow reduction.

2.3.6 Modelling with the Aggregated Storage Model (ASM)

The ASM allows the user to allocate a total (or aggregate) storage volume to each of the sub-catchments to assess the impact of storage on both the selected sub-catchment and the total downstream flow at the point of interest.

The flow data from the HEPs was inputted into the ASM to simulate the effect of attenuation from NFM interventions on the catchment hydrograph based on a user-defined 'Threshold Flow'. The threshold flow is a level that, once exceeded, would allow flow to enter the proposed NFM storage intervention. The scenarios were developed and optimised for a 100-year return period design storm.

The parameters can be optimised either for sub-catchment mitigation, or for overall catchment mitigation. In this study, reduction of the downstream peak flows at Midleton were prioritised.

3 Results

3.1 NFM Opportunity Mapping

Of the seven types of NFM considered, the highest scoring "NFM-type" was selected for each grid square. Figure 9 shows the most suitable NFM intervention type for each grid cell throughout the catchment area.

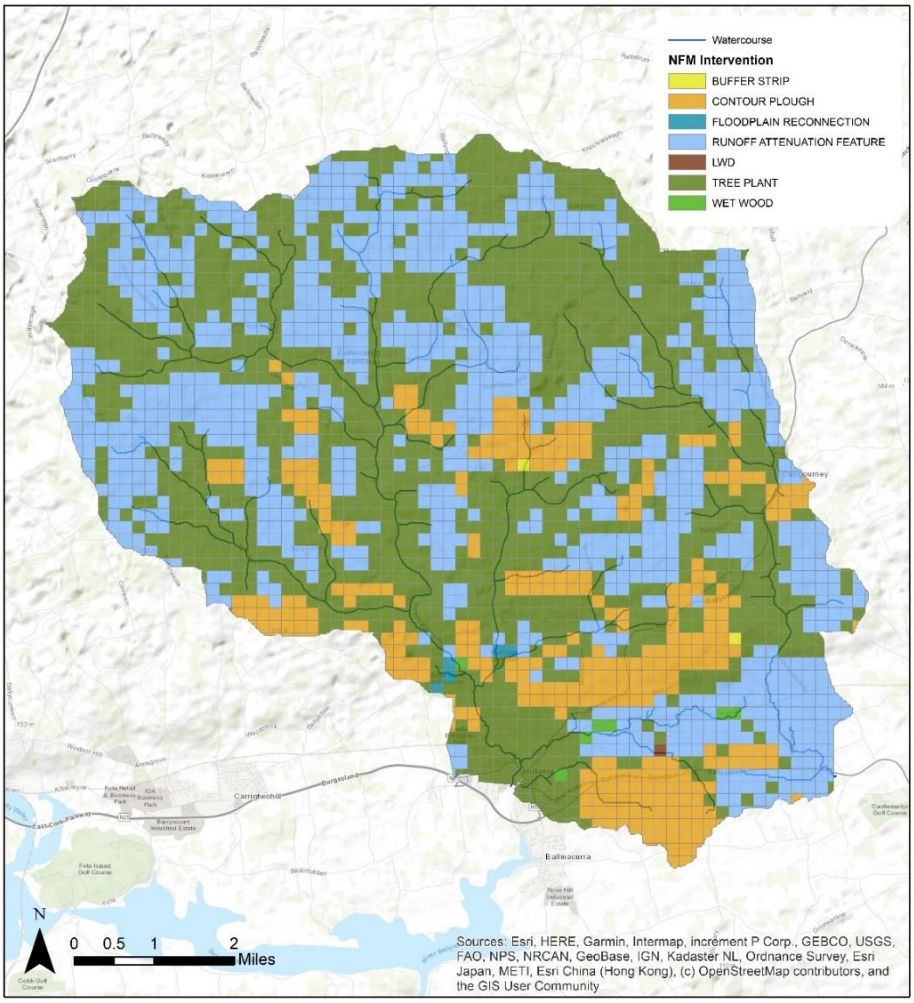


Figure 9: The highest scoring NFM intervention type for each grid square showing the potential for NFM (and NWRM) throughout the catchment

Tree Planting and Runoff Attenuation are the most common NFM intervention type, accounting for 47.56% and 37.96% of the catchment respectively. Conversely, large woody debris (LWD) was the highest scoring feature type for just one grid cell.

In Figure 9 an NFM-type was selected for a grid regardless of its overall score out of five, provided it was higher than the other six options. To avoid misrepresenting the potential of NFM interventions across the catchment, a threshold was set to ensure a minimum score was met before an NFM feature was selected.

The score was selected as 3 (out of 5), with the exception of Tree Planting and Runoff Attenuation interventions which was assigned as 3.75, owing to their higher frequency.

Figure 10 therefore shows the prioritised grid cells with the most suitable intervention type identified. While a proportion of the catchment is blank, this does not mean NFM is not feasible in these areas, only they are not the preferred locations for the seven selected NFM interventions due to catchment characteristics.

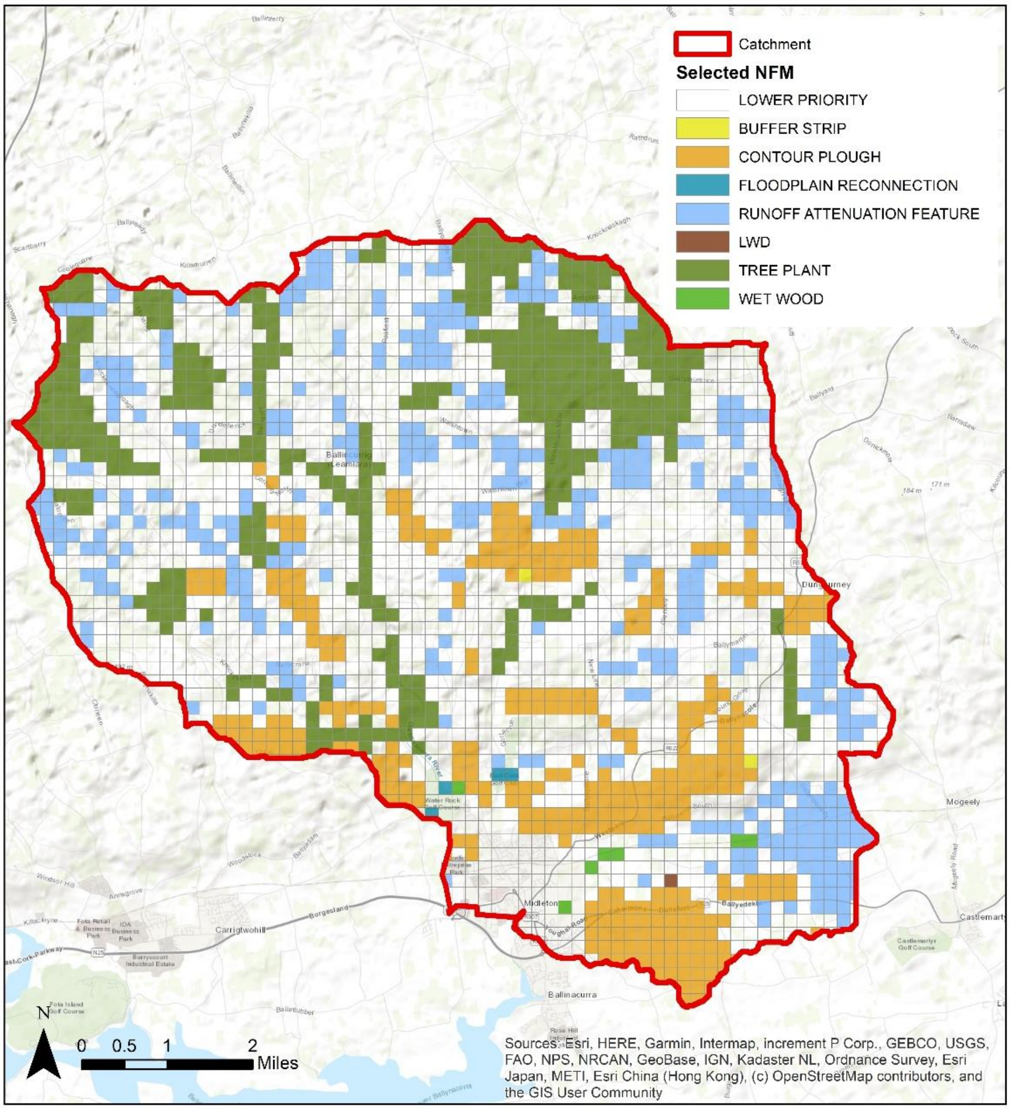


Figure 10: Proposed NFM Opportunity map, indicating the preferred NFM intervention throughout the catchment

Of the most appropriate areas in the catchment for NFM, Tree Planting remains the most suitable, scoring the highest in 34.56% of the selected area, closely followed by Runoff Attenuation at 34.06%. The spatial distribution of these interventions are largely in the upper and middle reaches of the catchment.

Contour Ploughing has also scored well across the catchment, especially in the middle reaches, and are proposed across 30.22% of the suitable catchment area.

The remaining interventions are largely in the middle to lower catchment, comprising Wet Woodland (0.58%), Floodplain Reconnection (0.33%), Buffer Strips (0.17%) and LWD (0.08%).

The highest scoring grid cell was 4.658 (out of 5) for Tree Planting and is located along the northern boundary of the catchment (Owenacurra 2) near Ballyogaha West. Similarly, the Tree Planting represents the top 208 highest scores, with Runoff Attenuation being the second highest scoring NFM intervention at 3.938, located at Knockeennagroagh also in the Owenacurra 2 sub-catchment.

Conversely, the lowest scoring grid cell was 3.008 for Floodplain Reconnection located within the Water Rock Golf Course in Owenacurra 7, with the second lowest scoring NFM intervention being Contour Ploughing, scoring 3.292 for a grid cell in Owenacurra 4, to the west of Shanavougha.

Generally, the areas of the catchment indicated to be most suitable for NFM and NWRM are located in the headwaters of the catchment in the north-west, north-east and south-east of the catchment. As shown in Figure 11, whilst NFM is feasible across the catchment it is best suited in the upper catchment areas, in particular in Owenacurra 1, 2, 3 and 8.

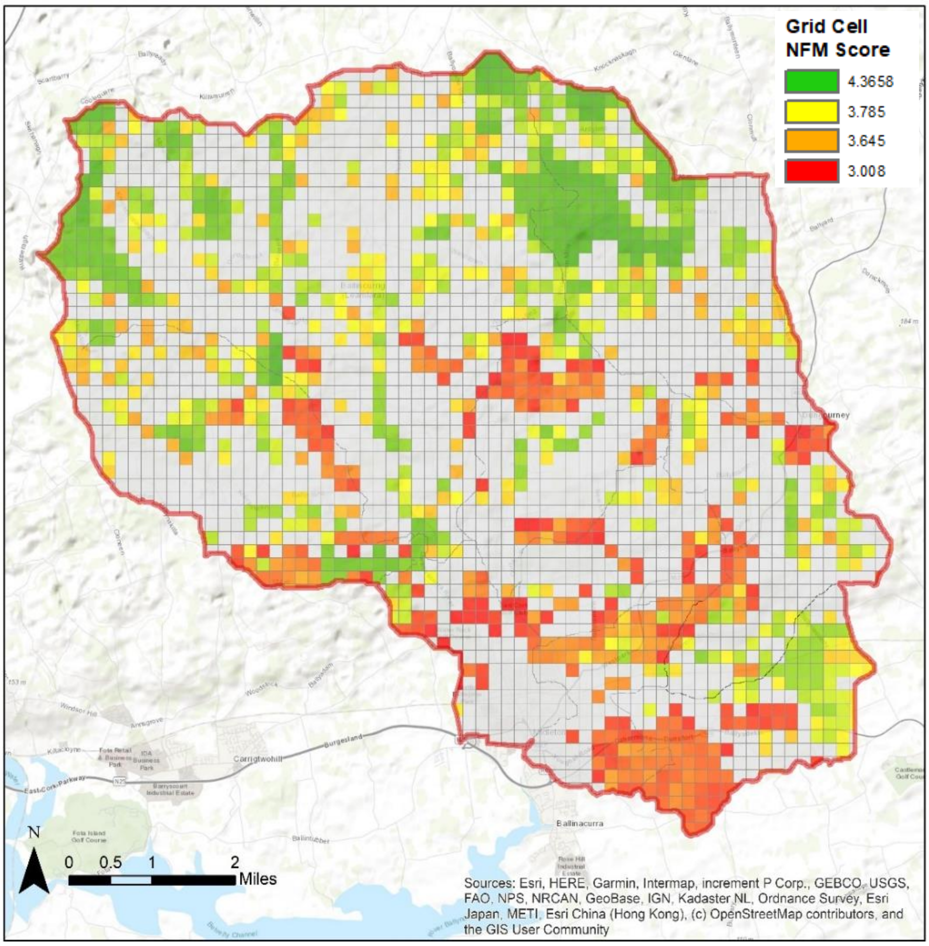


Figure 11: Map indicating the location of the preferred NFM locations throughout the Midleton catchment coloured on a graduated red, amber green scale to indicate the associated score; where green is the highest scoring cell and red is the lowest scoring cell (>3) of the preferred NFM interventions.

3.2 Hydrological Outputs

The results for the six NFM scenarios are presented below, in terms of percentage peak flow reduction at Midleton.

3.2.1 Scenarios A1, B1, A2 and B2

The peak flow reduction at Midleton for each of the first four scenarios are presented in Table 5. This shows that scenario B1 delivers the largest reduction in peak flow, at 9.4%. Often, it is not possible to make use of all available storage due to environmental, ecological, landowner-related and geotechnical constraints. Scenarios A2 and B2 show that 6.0% and 6.9% reduction of peak flow could be achieved if the overall storage volume was reduced by a third, to account for likely catchment constraints.

Table 5: Four scenarios with assumptions presented, tested using the ASM

Scenario:	**Catchment Storage Assumptions**	**Feature Storage Assumptions**	**Flow Peak Reduction at Midleton:**
A1	386,174m^3 utilised across all nine sub-catchments	~500m^3 per storage feature ~776 storage features	7.9%
B1	386,174m^3 utilised across all nine sub-catchments	<10,000m^3 per storage feature Maximum of 43 storage features	9.4%
A2	257,441m^3 utilised across all nine sub-catchments	~500m^3 per storage feature ~548 storage features	6.0%
B2	257,441m^3 utilised across all nine sub-catchments	<10,000m^3 per storage feature Maximum of 32 storage features	6.9%

3.2.2 Targeting storage volume in the most effective sub-catchments

All nine sub-catchments in scenarios A1, B1, A2 and B2 contribute to the overall reduction of peak flow downstream at Midleton. However, to prioritise which sub-catchments offer a greater reduction in overall flow peak, a high-level, indicative exercise to determine each individual sub-catchment's impact was conducted by removing the contributing component of each sub-catchment, one at a time.

The overall impact on flow reduction is measured and reported in Figure 12 and Figure 13 for scenarios A1 and B1, respectively. They show the distribution of each sub-catchment to the percentage peak flow reduction, graded on a red, amber, green scale. A higher percentage contribution (and therefore green colour) indicates more effective NFM interventions within each sub-catchment.

In summary, the two maps show that the sub-catchments with the greatest potential to contribute to flood reduction downstream are Owenacurra 1, 2 and 3. Therefore, the following scenarios A3 and B3 will focus on these.

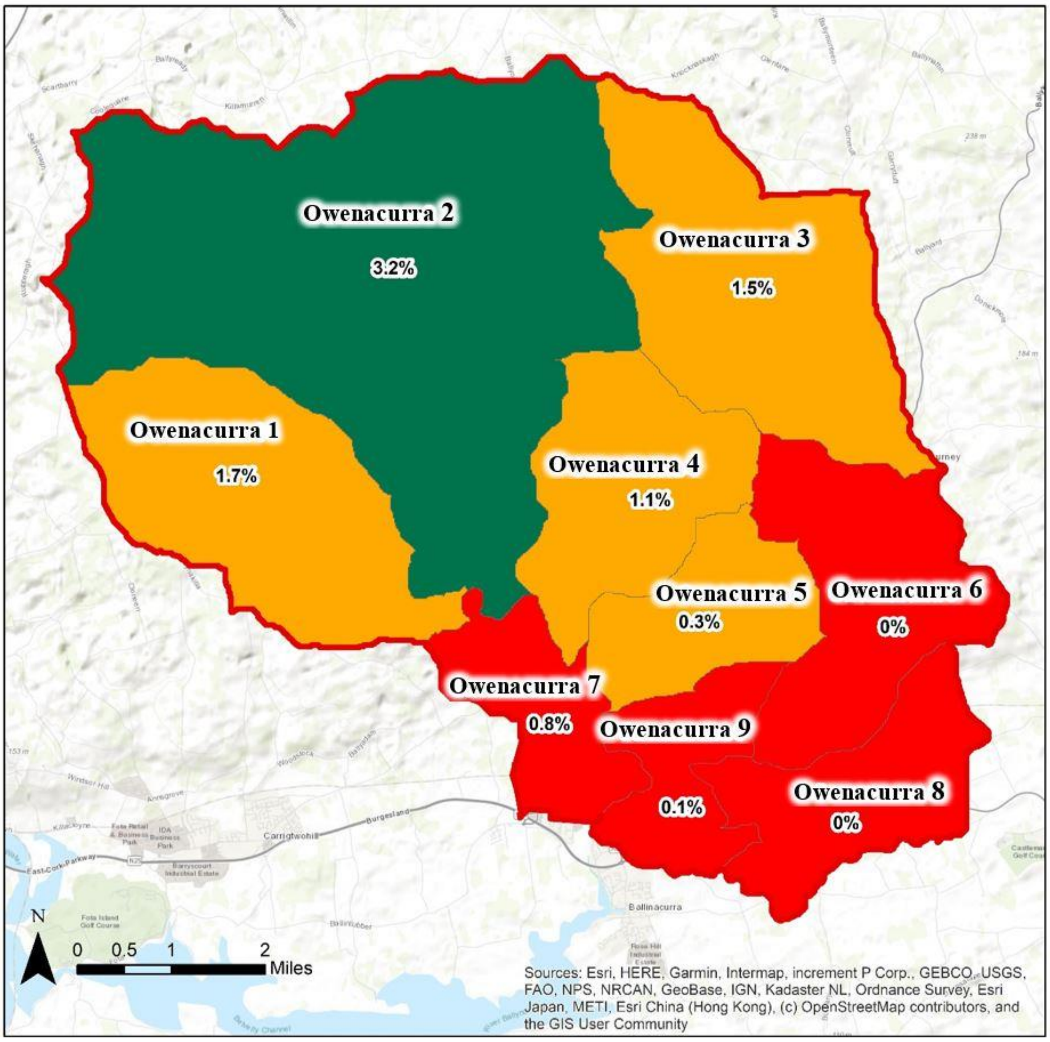


Figure 12: The distribution of percentage peak flow reduction across the sub-catchments for scenario A1

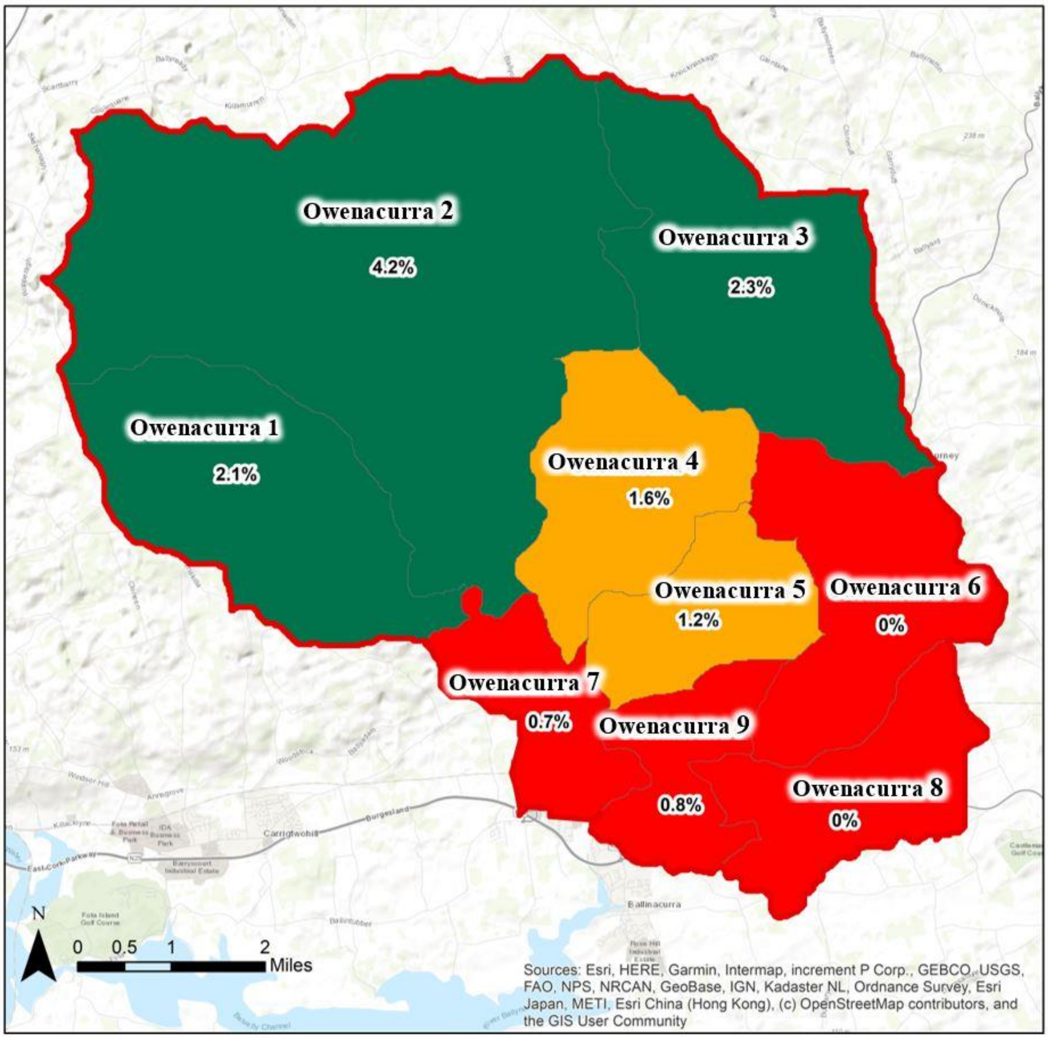


Figure 13: The distribution of percentage peak flow reduction across the sub-catchments for scenario B1

3.2.3 Scenarios A3 and B3

Table 6 shows that by targeting NFM storage interventions in sub-catchments Owenacurra 1, 2 and 3, comparable flow peak reductions to scenarios A2 and B2 can be achieved, using less total storage volume.

Table 6: Final two scenarios with assumptions presented, tested using ASM

Scenario:	Catchment Storage Assumptions	Feature Storage Assumptions	Flow Peak Reduction at Midleton:
A3	237,548m^3 utilised across sub-catchments Owenacurra 1, 2 and 3.	~500m^3 per storage feature ~476 storage features	6.1%
B3	237,548m^3 utilised across sub-catchments Owenacurra 1, 2 and 3.	<10,000mm^3 per storage feature Maximum of 18 storage features	6.9%

3.2.4 Summary of Scenario Results

Table 7 presents an overview of flow peak reduction for the six scenarios.

Table 7: Sub-catchment peak flow reductions for Owenacurra 1 – 9 and overall peak flow reduction at Midleton

Catchment:	**Percentage Peak Flow Reductions for Scenario:**					
	A1	**B1**	**A2**	**B2**	**A3**	**B3**
Owenacurra 1	9.1%	9.6%	6.9%	6.2%	9.1%	9.6%
Owenacurra 2	7.9%	9.6%	6.0%	7.3%	8.0%	5.1%
Owenacurra 3	6.0%	6.5%	6.2%	7.0%	6.0%	9.2%
Owenacurra 4	3.4%	8.1%	5.6%	6.3%	0.0%	0.0%
Owenacurra 5	5.4%	3.7%	3.5%	5.8%	0.0%	0.0%
Owenacurra 6	9.7%	11.2%	6.6%	8.5%	6.1%	6.1%
Owenacurra 7	8.4%	10.1%	6.4%	7.4%	6.5%	6.3%
Owenacurra 8	0.0%	8.0%	1.9%	6.9%	0.0%	0.0%
Owenacurra 9	6.4%	7.4%	4.6%	5.6%	5.0%	5.0%
Overall impact at Midleton:	7.9%	9.4%	6.0%	6.9%	6.1%	6.9%

In some cases, the sub-catchment flow reduction can benefit properties prone to flooding within the particular sub-catchment. However, this is beyond the scope of this study and would require further assessment.

3.2.5 Sensitivity testing

An analysis was performed to understand the impact the storage features designed for the 1 in 100-year event would have during smaller design storms. Table 8 shows the peak flow reduction at Midleton for the 1 in 10-year storm and the 1 in 50-year storm. It shows there would be no benefit for the 1 in 10-year storm, but reasonable benefits in the order of 3 to 4% for four of the six scenarios for the 1 in 50-year storm. The absence of benefit for the 1 in 10 year storm is likely due to storage parameters which have been optimised for a much larger storm event. As such, the timing of the filling and emptying of the storage features may not be appropriate for reducing the peak flow, or they may not fill up at all if the threshold flow for which they were designed is not reached by the 1 in 10 year event.

Table 8: Peak flow reduction during 1 in 10 and 1 in 50-year events if the storage was designed for the 1 in 100-year event

Scenario:	**Design Storm Return Period:**	
	1 in 10 year	**1 in 50 year**
A1	0.0%	3.7%
B1	0.0%	3.4%

Scenario:	Design Storm Return Period:	
	1 in 10 year	1 in 50 year
A2	0.0%	1.8%
B2	0.0%	1.2%
A3	0.0%	3.2%
B3	0.0%	2.9%

4 Summary and Discussion

This study analyses the potential of storing runoff and peak fluvial flow to mitigate flood risk. It does not account for tidal influence of the Owenacurra river at Midleton, or other sources of flood risk such as groundwater.

The NFM opportunity mapping identified that a variety of NFM interventions are suitable across the study area. However, Tree Planting, Runoff Attenuation and Contour Ploughing are the primary interventions considered suitable to mitigate the peak flow during the 1 in 100-year storm event.

The maximum possible flow reduction for the Midleton catchment using NFM approaches would be in the order of 10%. The CSE approach of using few larger storage structures is demonstrated to be more effective for this catchment than more traditional NFM storage interventions.

The most effective use of storage was demonstrated by Scenario B3, where up to 18 structures each storing up to 10,000m^3 are proposed to be installed in three headwater sub-catchments, Owenacurra 1, 2 and 3. These interventions would yield a total potential storage volume of 237,548m^3 and reduce the peak flows at Midleton by 6.9%. The traditional NFM approach was also demonstrated to be effective here, with approximately 476 storage features each holding an average volume of 500m^3 producing a 6.0% reduction in peak flow at Midleton.

If the proposed NFM interventions provide this amount of storage within each sub-catchment, this would alter the storm flow hydrograph due to a change in timing and peak of the hydrograph. The impact can be seen at the downstream extent of each sub-catchment and at the downstream extent of the full catchment at Midleton, as shown in Table 7.

It is worth noting that introducing interventions in the three headwater catchments, Owenacurra 1, 2 and 3, also produces flow reduction benefits in other sub-catchments e.g. Owenacurra 6, 7 and 9. This is because these catchments are ‘nested’, where water flows from the headwater catchments and through these ‘nested’ catchments before flowing through Midleton.

The mapping analysis shows that Tree Planting and Runoff Attenuation features are the most suitable type of NFM feature. Owenacurra 1, 2 and 3 show the highest proportion of land which is suitable for the introduction of NFM features. This aligns with scenarios A3 and B3, which indicate that these sub-catchments are most effective in terms of peak flow reduction.

There are benefits and drawbacks to both the CSE and traditional NFM approaches. Traditional techniques can be less formal, easier to get permissions for and quicker to implement. However, they rely on landowner engagement and many features are required to deliver the benefits. The larger ponds used in the CSE approach require less stakeholder and landowner engagement and relatively few of them are required to produce equivalent – or better – benefits. However, they require more extensive design, modelling, planning and each one requires a much larger area of land.

There are few examples where NFM is used to reduce flood risk in catchments in the order of 150km^2 because this is a new area under investigation. Arup are internationally recognised as leading in this new area of NFM application. However, it is important to note that NFM has been demonstrated to be effective at scales in the order of 10 - 40km^2 (e.g. Belford and Coatham Woods) and that these style of headwater catchments exist everywhere across the British Isles.

Therefore, the assumptions made in this study are applicable owing to the nature of the Midleton catchment comprising many smaller headwater catchments, of a size at which NFM is proven to be effective.

4.1 Delivering NFM in Midleton

4.1.1 High-level Cost Estimates

A high-level costing exercise has been undertaken using relevant information from the UK Environment Agency's 'Cost estimation for land use and run-off – summary of evidence'[13], other literature and SPON's Civil Engineering and Highways Pricing Book 2017[14]. The mapped NFM opportunities in Figure 10 were considered in this analysis.

In this section, one traditional NFM scenario has been costed (A2) and one Catchment Systems Engineering scenario has been costed (B1).

It is assumed that Runoff Attenuation features have the potential to be constructed using either a soil bund (a cheaper structure) or a timber leaky dam (a more expensive structure, which uses a negligible footprint and requires no soil for construction) as indicated in Table 1. The derivation of the costs for construction and maintenance using a traditional NFM approach are detailed below.

Table 9 shows the typical costs per unit based on the interventions considered. As discussed above, the runoff attenuation features were assumed to be either a soil bund construction with a 30m long, 1.5m high embankment with 1:3 side slopes and a crest width of 1m (lower cost estimate), or a timber leaky structure constructed to 30m of hard wood beams buried c.1.5m into the earth, and reaching a height of 1.5m above ground level (upper cost estimate).

A differentiation between floodplain reconnection and offline storage features is noted in Table 9. The former assumes a more subtle approach to reconnecting floodplains where opportunities have been identified from the mapping analysis. This is aligned with the traditional approach to NFM (Scenarios A) and is costed spatially, per hectare. The CSE approach (Scenarios B) which utilises designed offline storage features, each one containing <10,000m^3, is costed per 1,000m^3 of storage.

[13] Environment Agency, UK (2015) Cost estimation for land use and run-off – summary of evidence.
[14] SPON Press (2017) Civil Engineering and Highway Works Price Book, edited by AECOM.

The unit cost of the runoff attenuation features were estimated using SPON's Civil Engineering and Highways Pricing Book14 whilst all other costs were derived from the Environment Agency literature13 and then converted to Euros using the following ratio £1 : €1.12.

Table 9: NFM intervention cost ranges per unit

Intervention	Lower Estimate	Upper Estimate
Runoff Attenuation feature	€3,680	€12,260
Large Woody Debris	€448	€840
Contour Ploughing	€3.36 per ha	€5.60 per ha
Tree Planting	€2,025.95 (mean cost per plantable ha)	€3,181.30 (mean cost per plantable ha)
Wet Woodland	€1,680 per ha	€2,576 per ha
Floodplain Reconnection (A) Offline Storage Features (B)	€11,200 per ha €14,930 per 1,000m^3	€16,800 per ha €22,390 per 1,000m^3
Buffer Strips	€35.84 per ha	€56 per ha

Tree Planting

The cost of tree planting varies considerably as a function of three parameters:

- The existing land use within each grid square.
- The percentage of each grid square on which it is assumed that trees would be planted.
- The tree planting density.

These three parameters are linked. For example, the existing land use within each grid square is used to determine the tree planting density. Moreover, the percentage of each grid square available for planting would also depend on the existing land use. Background assumptions have been made regarding the percentage of each grid square available for tree planting, and the planting density, based on the existing land use. These are summarised in Table 10. For each existing land use type, consideration was given to the likely achievable tree density. For example, the achievable planting density within an area predominantly comprising coniferous forest would be significantly less that the potential available planting density within an area predominantly comprising pastures.

Table 10: Assumptions of available land area and tree planting density corresponding to existing land use.

Existing Land Use	Percentage of each grid square assumed to be available for tree planting %	Tree planting density (per ha)	
		Lower	Upper
Transitional woodland-scrub	30%	500	1,110
Mixed forest	20%	500	1,110
Land principally occupied by agriculture, with significant areas of natural vegetation	40%	1,110	1,600
Coniferous forest	20%	500	1,110
Pastures	25%	1,110	2,250

The information from Table 10 was used to develop high level cost estimates grouped by existing land use, as shown in Table 11. The total catchment area within which tree planting has been prioritised is 2587.5 ha, represented by 414 grid squares. However, within this total area, it is assumed that 612 ha will be developed for tree planting.

Table 11: Upper and lower cost estimates for the 612 plantable ha within the 414 grid squares (2,587.5 ha total area) prioritised for tree planting within the catchment.

Existing Land Use	No. of Grid Squares	Percentage of total land area prioritised for tree planting %	Lower Cost Estimate	Upper Cost Estimate
Transitional woodland-scrub	61	14.7%	€192,150	€ 294,630
Mixed forest	57	13.8%	€119,700	€ 183,540
Land principally occupied by agriculture, with significant areas of natural vegetation	12	2.9%	€77,280	€ 99,993.60
Coniferous forest	152	36.7%	€319,200	€ 489,440
Pastures	132	31.9%	€531,300	€ 878,955
		TOTAL:	€ 1,239,630.00	€ 1,946,558.60

Scenario A2

Upper and lower cost estimates for storage-based NFM features, represented in scenario A2, are shown in Table 12. Distributing these storage-based features, as recommended in Figure 10, is estimated to deliver a peak flow reduction of 6% for the 1 in 100-year design event at Midleton.

Table 12: Upper and lower cost estimates for the storage-based NFM features distributed throughout the NFM catchment for scenario A2.

Intervention	Quantity	Lower Cost Estimate	Upper Cost Estimate
Runoff Attenuation	548	€2,015,086 (548 Earth bunds)	€4,367,170 (274 Earth Bunds and 274 Timber leaky dams)
Wet Woodland	43.75 ha	€14,700	€22,540
Floodplain Reconnection	24.08 ha	€269,696	€404,544
Total		€2,299,482	€4,794,254

When all types of NFM (including non storage-based) are included from the refined NFM opportunity mapping shown in Figure 10, the cost estimate rises. It should be noted that Figure 10 is intended to identify where opportunities exist, not to show what the catchment needs to be altered to. However, for the purposes of this study it is appropriate to identify the potential costs of all the identified opportunities. Table 13 shows the upper and lower cost estimates if all possible NFM features were implemented within the Midleton catchment.

Table 13: A breakdown of construction costs for the proposed NFM interventions in Midleton if all NFM features were included in addition to the storage-based options from scenario A2.

Intervention	Quantity	Lower Cost Estimate	Upper Cost Estimate
Runoff Attenuation	548	€2,015,086 (548 Earth bunds)	€4,367,170 (274 Earth Bunds and 274 Timber leaky dams)
Large Woody Debris	10	€4,480	€8,400
Contour Ploughing	2,127 ha	€7,145	€11,911

Intervention	**Quantity**	**Lower Cost Estimate**	**Upper Cost Estimate**
Tree Planting	612 ha	€ 1,239,630	€ 1,946,558.60
Wet Woodland	8.75 ha	€14,700	€22,540
Floodplain Reconnection	24.08 ha	€269,696	€404,544
Buffer Strips	12.5 ha	€448	€700
Total		€3,551,185	€6,761,824

Several assumptions have been made to produce the cost estimates in Table 13. It was assumed that a total of 548 RAFs could be positioned within the 408 grid squares where RAFs are prioritised. This equates to an average of 1.34 RAFs per grid square, which was deemed to be reasonable based on the geospatial analysis. For grid squares where LWD is prioritised, an assumption has been made that 10 can be positioned within, and where buffer strips have been prioritised, it was assumed that 10% of land is available. Tree planting assumptions were discussed above. For all other interventions it is assumed (for costing purposes) the entire grid is being transformed, which presents a very conservative estimate.

Scenario B1

Costing of Scenario B1 is shown in Table 14 with storage-based features only and Table 15 including both storage and non-storage based NFM features. For clarity, the costs incurred to construct the storage-only scheme outlined in Table 14 would produce a 9.4% reduction in downstream peak flow.

Table 14: Scenario B1 for storage-only NFM features

Intervention	**Quantity**	**Lower Cost Estimate**	**Upper Cost Estimate**
Runoff Attenuation	0	N/A	N/A
Offline Storage Features	386,000m^3 Across ~43 features	€5,762,980	€8,642,540
Total		€5,762,980	€8,642,540

Table 15: Scenario B1 including both storage-based and non-storage based NFM features

Intervention	Quantity	Lower Cost Estimate	Upper Cost Estimate
Runoff Attenuation	0	N/A	N/A
Large Woody Debris	10	€4,480	€8,400
Contour Ploughing	2,127 ha	€7,145	€11,911
Tree Planting	612 ha	€ 1,239,630	€ 1,946,558.60
Wet Woodland	8.75 ha	€14,700	€22,540
Offline Storage Features	386,000m^3 Across ~43 features	€5,762,980	€8,642,540
Buffer Strips	12.5 ha	€448	€700
Total		€ 7,029,383	€ 10,632,650

All cost estimates assume that civil engineering and agricultural contractors would deliver the works. Theoretically, a proportion of these interventions could be delivered using a volunteer workforce, or by landowners/farmers through the provision of some technical information. The costs also include the materials and workmanship of constructing the interventions. Mobilisation and temporary site cabins are not factored into the cost due to the uncertainty of the delivery mechanism at this stage in the process. For instance, the context is likely to differ depending on whether a local contractor, major contractor, landowner or volunteer force were commissioned to undertake the work, resulting in potentially highly variable costs.

As discussed in Section 2.3.3, the four NFM features in Table 13 other than Runoff Attenuation, Floodplain Reconnection and Wet Woodland have not been included in the ASM Tool analysis. It is likely that these features would reduce the peak flow at the catchment scale to some degree, because they roughen the surface of the land and/or watercourses, increase infiltration and intercept rainfall. However, it is likely that these effects would have less of an impact to storage-based techniques during the design storms being considered in Midleton. For the purposes of this study, it is conservative to assume these NFM features deliver no reduction of peak flow for the 1 in 100-year design storm. It should be noted, however, that these interventions provide multiple ecosystem services benefits other than flood risk and would create a more resilient catchment.

No allowance has been made for mobilisation costs, present value maintenance costs or optimism bias.

These additional costs could be significant, depending on 'ownership' of the NFM assets and the desired design-life of the scheme. For instance, some features may need to be replaced periodically (i.e. LWD are assumed to need replacing every ~7 years and hard wood timber leaky dams may need replacing after ~33 years) and annual maintenance is also required to ensure interventions are not blocked or silted up. The design life can be specified at the outset of the project. Extending the design life beyond 33 years will mean that certain features may have to be replaced completely due to the assumption that timber leaky dams may not last for longer.

It is assumed that annual maintenance costs €2,800 per $10km^2$ of catchment area (based on a trial performed by the Environment Agency North East Region in Belford, Northumberland) which would equate to ~€43,000 per year for the Midleton catchment (being approximately $154km^2$). This is based on the maintenance being delivered centrally, rather than provided by the landowners. With these additional elements included in the cost estimate, assuming a 30-year design life, the total costs are expected to increase by approximately €860,000 in present-value costs.

A summary of upper and lower estimates of the Project Cost Total including component items, based on OPW costing guidance, is provided in Table 16 below for Scenario A1 and Scenario B.

Table 16: Project Total Costs including component items developed using OPW guidance

	Scenario A2 (including non-storage-based features)		**Scenario B1 (excluding non-storage-based features)**	
	Lower	**Upper**	**Lower**	**Upper**
Gross Construction Cost Estimate	€3,551,185	€ 6,761,824	€ 5,762,980	€ 8,642,540
Prelims (15%)	€ 532,678	€ 1,014,274	€ 864,447	€ 1,296,381
Baseline Construction Cost	**€ 4,083,863**	**€ 7,776,098**	**€ 6,627,427**	**€ 9,938,921**
Contingency (20%)	€ 816,773	€ 1,555,220	€ 1,325,485	€ 1,987,784
Construction Cost Subtotal	**€ 4,900,635**	**€ 9,331,317**	**€ 7,952,912**	**€ 11,926,705**
Land Acquisition (15%)	€ 612,579	€ 1,166,415	€ 994,114	€ 1,490,838
Fees and Supervision (10%)	€ 408,386	€ 777,610	€ 662,743	€ 993,892

	Scenario A2 (including non-storage-based features)		Scenario B1 (excluding non-storage-based features)	
	Lower	Upper	Lower	Upper
Site Investigation and Surveys Estimate	€ 50,000	€ 80,000	€ 50,000	€ 80,000
Capital Cost Total	**€ 5,971,601**	**€ 11,355,342**	**€ 9,659,769**	**€ 14,491,435**
Maintenance (NPV)	€ 860,000	€ 940,000	€ 860,000	€ 940,000
Project Cost Total	**€ 6,831,601**	**€ 12,295,342**	**€ 10,519,769**	**€ 15,431,435**

4.1.2 Delivering NFM in Midleton

Delivery of NFM schemes (or NWRM) is still a relatively new concept in Ireland and requires development of appropriate funding and institutional arrangements.

4.1.2.1 Policy

Flood risk management policy in Ireland is outlined by the National Flood Risk Policy (2004) and the Inter-Departmental Flood Policy Coordination Group[15]. While the adopted policy does not specifically mention Natural Flood Management, it does promote a 'catchment-based' approach and greater emphasis on 'non-structural' flood relief measures.

Core components of national flood policy and the EU Flood Directive[16] are being delivered under the national Catchment Flood Risk Assessment and Management (CFRAM) programme. The CFRAM programme aimed to provide a clear picture of flood risk in areas of potentially significant flood risk and to set out how to manage the flood risk effectively and sustainably. The process included a Preliminary Flood Risk Assessment (2012), preparation of flood maps (2015) and preparation of 29 Flood Risk Management Plans (FRMPs, 2017). The use of non-structural measures are referenced within the FRMPs as land use management and natural water retention measures and pilot studies have been proposed in some of the FRMPs.

[15] OPW (2020) Flood Risk: Policy and Co-ordination. Online. Available at: https://www.gov.ie/en/policy-information/aba306-flood-risk-policy-and-co-ordination/. Accessed on: 13/08/20
[16] European Directive on the Assessment and Management of Flood Risks (2007/60/EC) and Irish Law (Statutory Instrument No. 122 of 2010)

4.1.2.2 Potential Delivery Routes

There are numerous possible project delivery options based on the route chosen at each decision level (project lead, consenting route, funding pathway and maintenance responsibilities) as outlined in Figure 14.

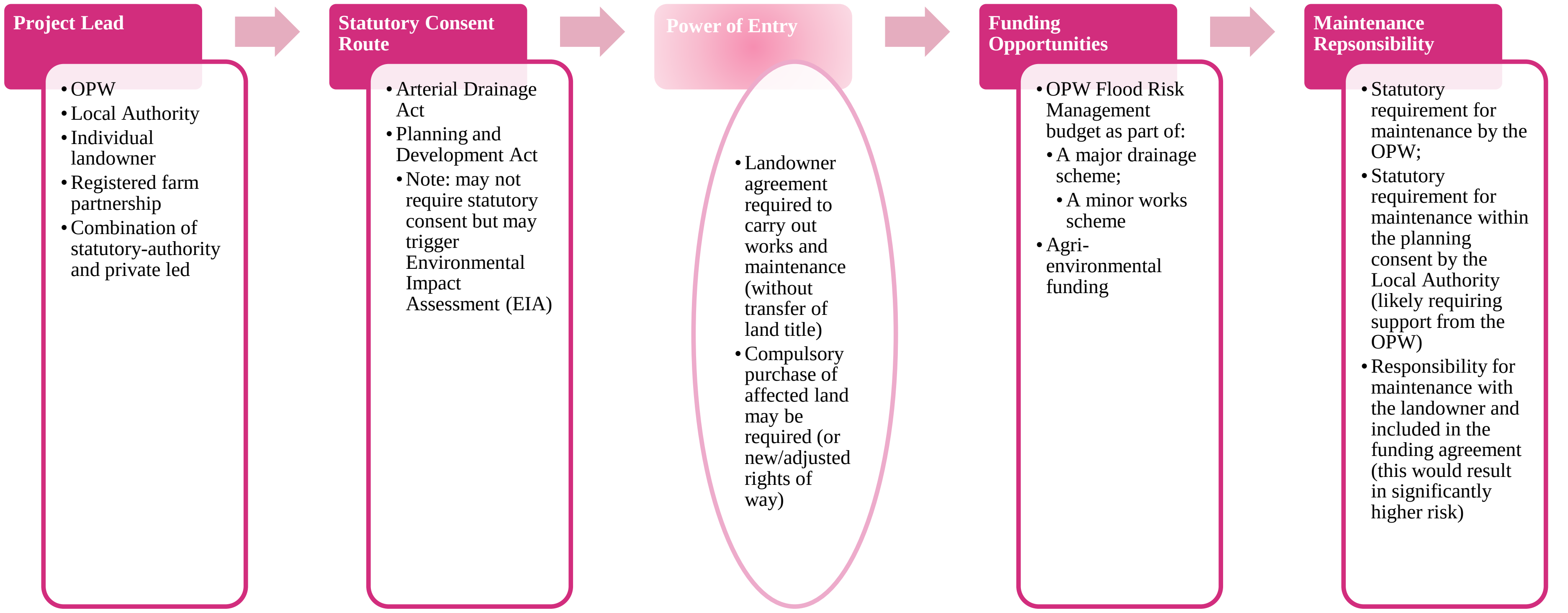


Figure 14: Outline of the potential delivery routes for NFM in Midleton

There are differing levels of risk and requirements associated with different delivery routes, with privately led schemes having less control and less certainty in the delivery of the desired outcome compared to a statutory led scheme. In terms of funding, agri-environmental funding through the Rural Development Programme 2014 - 2020 is one potential route, with two main funding streams that farmers can access:

- The Green, Low-carbon, Agri-environment Scheme (GLAS); and
- Basic Payment Scheme (BPS), that can be coupled with the Greening Payment.

Generally, the maximum GLAS payment is €5,000 per year. However, some farmers undertaking particularly challenging actions may qualify for GLAS+ and for a top-up payment of up to €2,000 per year. For example, measures that address NFM include minimum tillage, planting a grove of native trees, planting new hedgerows and creating riparian margins[17]. For the BPS, payment value is determined annually based on payments for the previous financial year, land area and the subsequent amount of entitlements with a minimum amount of €100. This can be topped up with the Greening Payment, with an average payment of €100 per hectare, based on measures such as crop diversification, ecological focus areas and protection of permanent grassland.

However, agri-environmental funding is unlikely to be available at the scale required to effect significant change in the Midleton catchment and the timescale of funding is relatively short. It is therefore considered likely that the majority of funding would still need to be sourced from OPW flood risk management budget.

Considering the lack of example studies in Ireland and established landowner-led delivery guidance and funding, it may be difficult to establish a privately led NFM scheme in Midleton. For a scheme to have reliable benefits, it would need to be delivered through a strong statutory mechanism such as the Arterial Drainage Act or the Planning Acts, accompanied by legal instruments granting powers of entry for construction and maintenance. Anything less robust carries a significant risk of the scheme not being fully deliverable or falling into disrepair.

[17] Department of Agriculture, Food and Marine. GLAS Structure. Available at: https://www.agriculture.gov.ie/media/migration/farmingschemesandpayments/glastranche1/GLAS Structure240215.pdf. Accessed 13/08/20.

5 Conclusions and Recommendations

This study seeks to provide an evidence base to demonstrate the extent to which Natural Flood Management (NFM) measures could reduce and attenuate peak flows in the Owenacurra and Dungourney catchments and provide flood risk mitigation in Midleton, located downstream. Using a combination of hydrological modelling and GIS analysis, the peak flow of nine sub-catchments flowing into Midleton have been analysed. Using an Arup-developed Aggregate Storage Model (ASM) and NFM feasibility tool, the potential impact of seven NFM interventions on peak flow have been analysed. This was then mapped to show prioritised locations for NFM opportunities throughout the Owenacurra and Dungourney catchment.

The mapping analysis showed that Tree Planting and Runoff Attenuation features (RAFs) are the most suitable NFM interventions within this catchment. This demonstrates that adding storage volume to the catchment is appropriate. The maximum achievable reduction in peak flow for the 1 in 100-year flood event at Midleton is 7.9% (scenario A1) using traditional NFM storage techniques and 9.4% (scenario B1) using the CSE approach. However, targeting NFM intervention measures in three headwater sub-catchments, Owenacurra 1, 2 and 3, produces the most effective peak flow reduction at Midleton.

Moreover, many of the most suitable locations for interventions were identified as being within these three sub-catchments from the GIS mapping analysis. Results from the two different approaches are comparable, at 6.1% for the traditional NFM approach (scenario A3) and 6.9% for the CSE approach (scenario B3). The targeted approach outlined by Scenarios A3 and B3 also provided localised flood peak reduction in three additional nested sub-catchments covering the northern half of Midleton and Water Rock Golf Course and up to Ballymartin in the East (Owenacurra 6, 7 and 9).

The results presented are highly conservative, an approach which is consistent with the Hydrology Report[11] but may underestimate the potential benefits of NFM in terms of peak flow reduction at Midleton.

NFM measures have adaptive capacity to mitigate climate change by increasing a catchment's resilience to climate change. NFM measures can reduce peak flows and increase the time to peak creating a buffer to help mitigate the adverse impacts of climate change. A scaling factor which increased the 1 in 100 year modelled peak flow by 14% has been included in the analysis, which can be considered to accommodate allowance for climate change.

When considering both storage and non-storage based NFM measures, by applying a traditional NFM approach a reduction of around 6% could be achieved for €6.8m-€12.3m project total cost.

If a CSE approach was adopted, a peak flow reduction in the order of 10% could be achieved for a project total cost of €11.1m-€15.5m This excludes non-storage based NFM measures.

Reduction of peak flow by 6-10% through NFM could lead to a minor reduction in the extent of structural flood defences within the Owenacurra fluvially dominated area of Scheme Area, notwithstanding the potential provision of ecosystem services resulting from the interventions.

However, to put the scale of this potential reduction into context, it should be noted that the implementation of Option 1C, the storage and direct defences option presented at PPD2, would result in approximately 30% reduction in peak flow.

It is concluded that the reduction in structural flood defence requirements along the Owenacurra would be minimal and in the context of the scale of intervention, the costs, landowner engagement required and the logistics of construction and maintenance of NFM in this area, it is evident that a Natural Flood Management solution is not technically viable as an option or even in combination with other measures.

However, NFM could be considered as a future measure within the Climate Change Adaptability Plan. Further investigation should be undertaken which could include:

- Evaluation of whether peak flow reduction within any particular sub-catchments could be beneficial to properties within those sub-catchments;
- More detailed modelling to refine the design storms. At present the analysis is conservative, so the peak flow reduction is likely to improve using more detailed modelling;
- In-depth geospatial analysis to determine site-specific locations suitable for NFM interventions, taking into account landowner access, environmental, geotechnical and ecological constraints as well as potential benefits; and
- CSE was identified as having significant practical potential to reduce flow peaks and improve resilience within the catchment. It is strongly recommended that a pilot study is investigated, as CSE situated throughout the catchment upstream of Midleton may be a suitable approach to take forward in the Climate Change Adaptability Plan for the FRS, particularly as new sites can be added as time progresses.

Appendix A

NFM Scoring Criteria

Corine Land-Use Code	Description	RUNOFF ATTENUATION FEATURE	FLOODPLAIN RECONNECTION	LWD	TREE PLANT	WET WOOD	BUFFER STRIP	CONTOUR PLOUGH
Code_112	Discontinuous urban fabric	1	1	2	3	1	1	1
Code_121	Industrial or commercial units	1	1	1	1	1	1	2
Code_142	Sport and leisure facilities	2	3	1	1	1	1	1
Code_211	Non-irrigated arable land	3	2	3	2	2	4	5
Code_231	Pastures	5	4	4	3	3	3	3
Code_242	Complex cultivation patterns	2	2	3	1	1	5	5
Code_243	Land principally occupied by agriculture, with significant areas of natural vegetation	3	3	4	4	3	5	4
Code_312	Coniferous forest	1	3	5	4	3	1	3
Code_313	Mixed forest	1	4	5	4	4	1	3
Code_324	Transitional woodland-scrub	4	4	5	5	4	1	3

Runoff route length (m)	RUNOFF ATTENUATION FEATURE	FLOODPLAIN RECONNECTION	LWD	TREE PLANT	WET WOOD	BUFFER STRIP	CONTOUR PLOUGH
0	1	1	3	3	3	3	3
<500	2	2	3	3	3	3	3
<1000	3	3	3	3	3	3	3
<1500	4	4	3	3	3	3	3
>1500	5	5	3	3	3	3	3

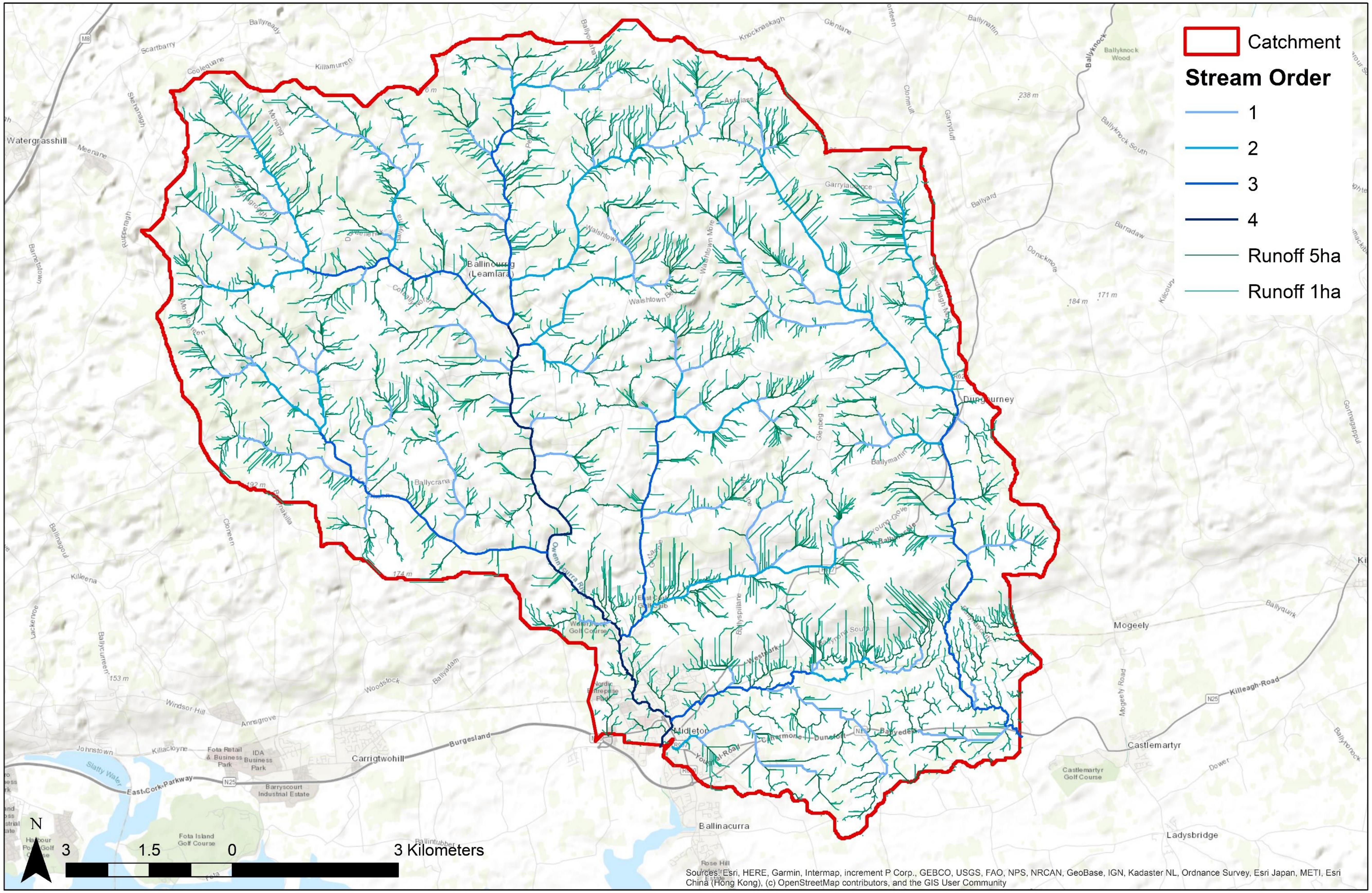
Ecosystem Service	RUNOFF ATTENUATION FEATURE	FLOODPLAIN RECONNECTION	LWD	TREE PLANT	WET WOOD	BUFFER STRIP	CONTOUR PLOUGH
Cost	3	1	4	5	5	5	5
Funding	1	1	3	5	3	5	5
Maintenance	5	3	3	5	4	5	4
Life Expectancy	3	3	1	3	5	5	5
Flood (Fluv)	4	5	4	2.5	4	2	1
Flood (SW or GW)	5	4	4	4	4	2	3
Air Quality	1	1	1	4	3	2	2
Health Access	1	2	1	4	2	2	1
Low Flows	2	3	3	3	4	1	1
Climate regulation	2	3	4	5	5	2	2
Habitat	3	4	4	5	5	2	2
Water Quality	4	3	5	4	4	5	5
Cultural Activity	1	2	2	4	3	2	2
Aesthetic Quality	1	4	4	4	4	2	2

% Area in the 1 in 100 year Floodplain	RUNOFF ATTENUATION FEATURE	FLOODPLAIN RECONNECTION	LWD	TREE PLANT	WET WOOD	BUFFER STRIP	CONTOUR PLOUGH
<5	5	1	1	5	2	5	5
<10	4	2	2	5	3	5	5
<25	3	3	3	4	3	4	4
<50	2	4	4	4	4	3	3
>50	1	5	5	3	4	2	2

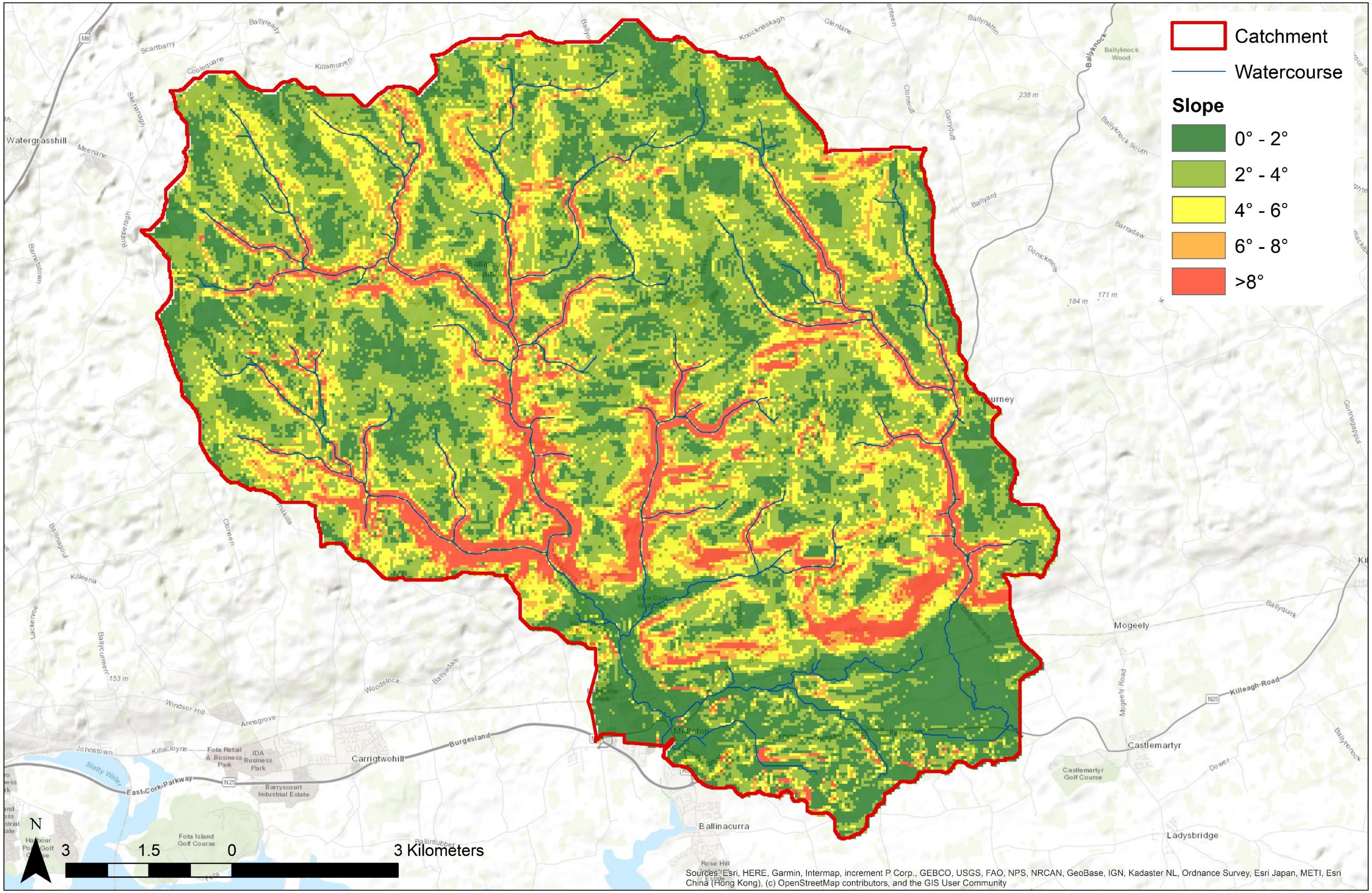
SLOPE RANGE (°)	RUNOFF ATTENUATION FEATURE	FLOODPLAIN RECONNECTION	LWD	TREE PLANT	WET WOOD	BUFFER STRIP	CONTOUR PLOUGH
0-2	5	5	5	4	5	1	2
2-4	4	4	5	4	4	2	3
4-6	3	3	5	4	3	4	5
6-8	2	2	4	4	2	2	5
>8	1	1	4	4	1	1	1

Appendix B

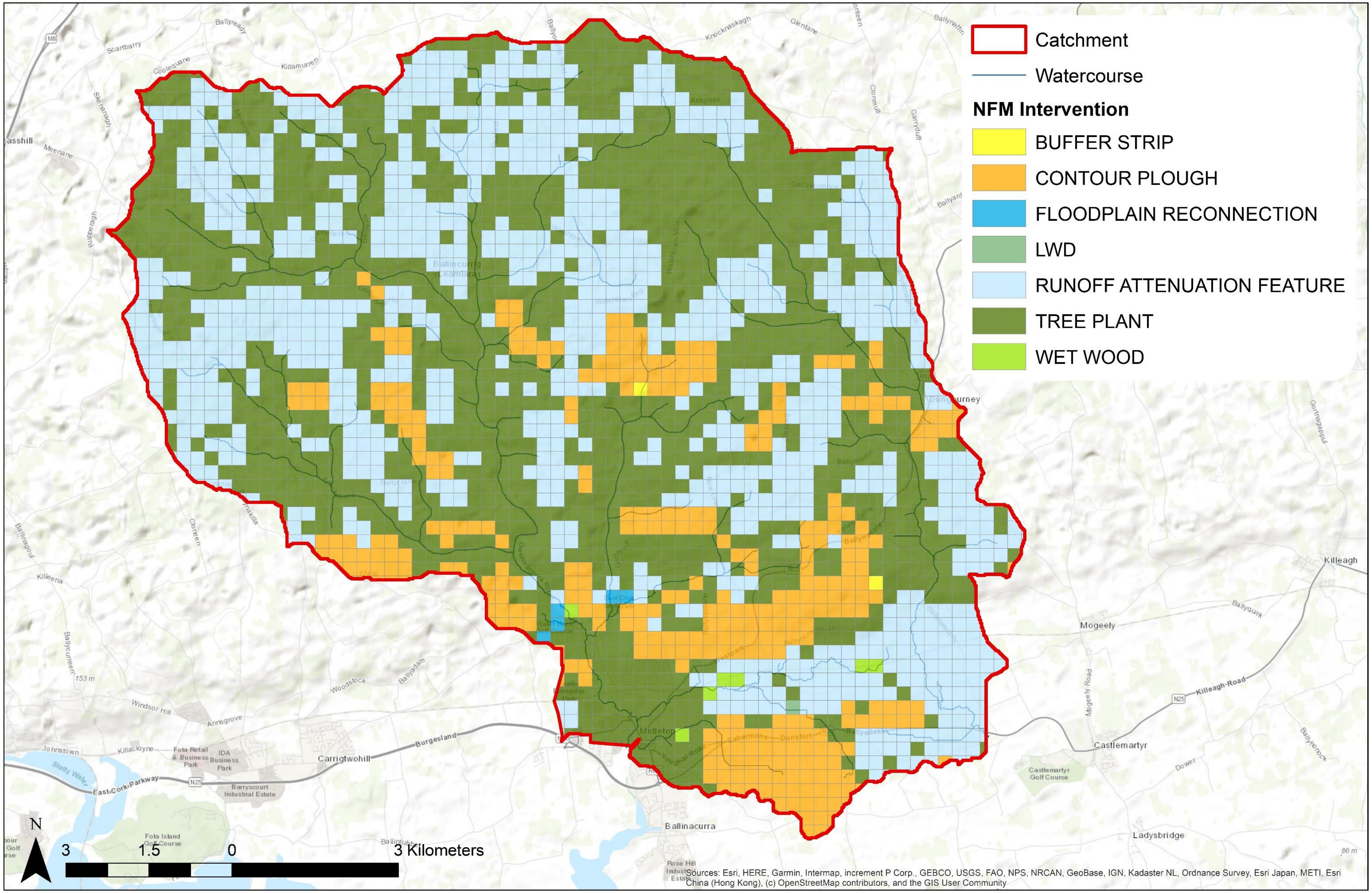
NFM Mapping Analysis Figures

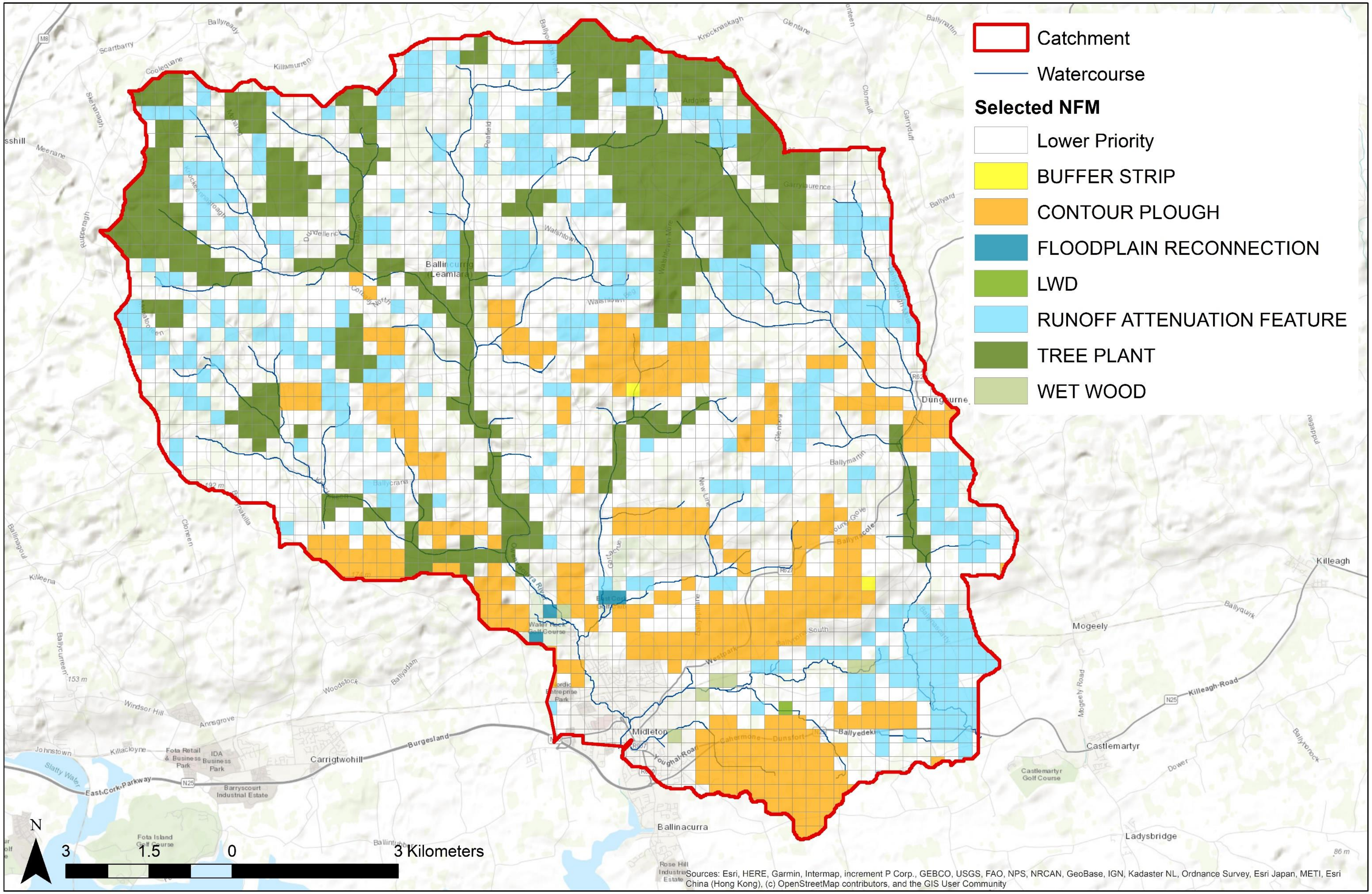


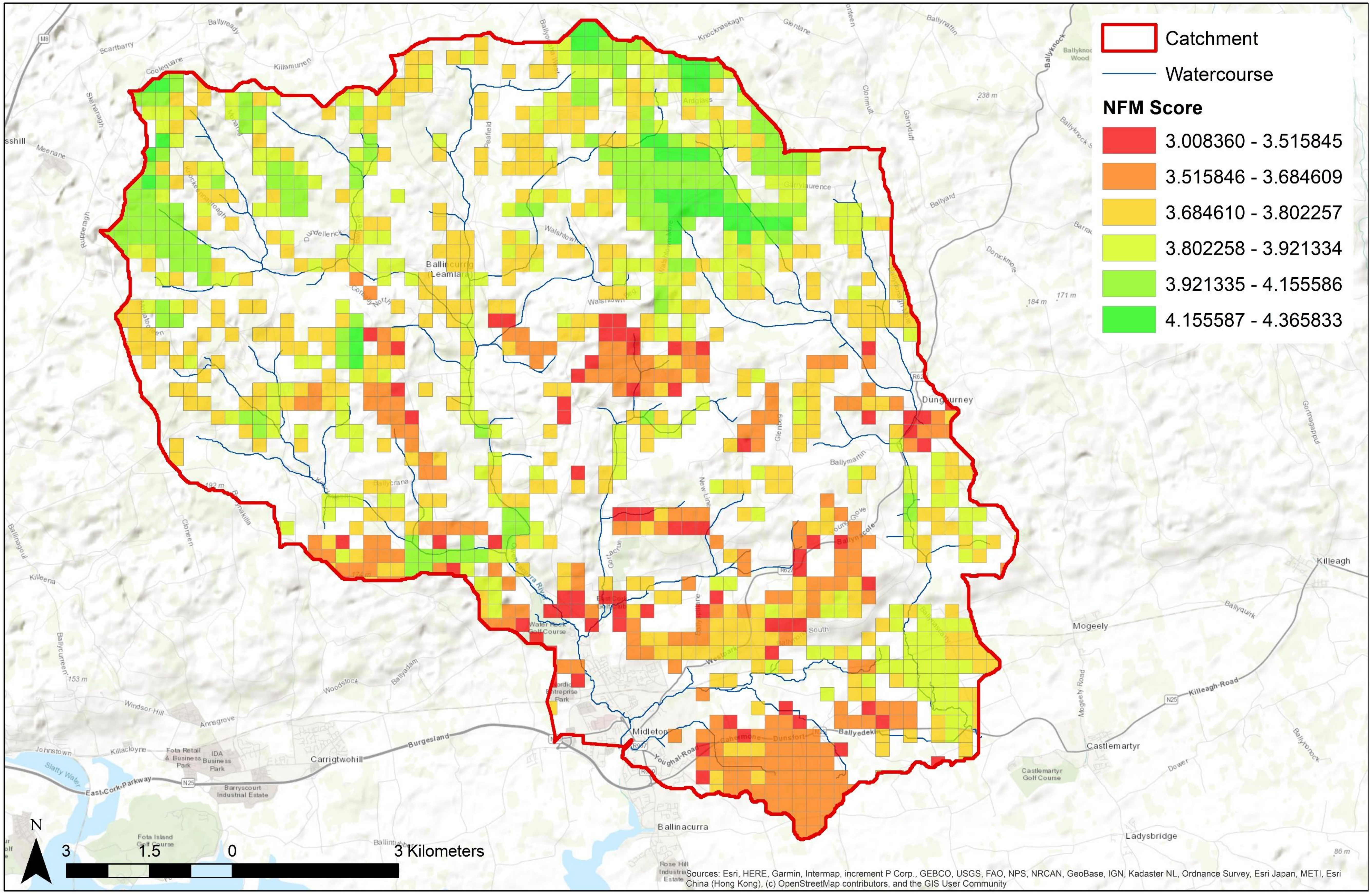
Catchment
Stream Order
1
2
3
4
Runoff 5ha
Runoff 1ha
N
3
1.5
0
3 Kilometers
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community
Watergrasshill
Ballincurrig (Leamlara)
Dungourney
Mogeely
Castlemartyr
Midleton
Carrigtwohill
Ballinacurra
Ladysbridge



Catchment
Watercourse
Slope
0° - 2°
2° - 4°
4° - 6°
6° - 8°
>8°
N
3
1.5
0
3 Kilometers
Watergrasshill
Carrigtwohill
Mogeely
Castlemartyr
Ballinacurra
Ladysbridge
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community


Catchment
Watercourse
NFM Intervention
BUFFER STRIP
CONTOUR PLOUGH
FLOODPLAIN RECONNECTION
LWD
RUNOFF ATTENUATION FEATURE
TREE PLANT
WET WOOD
N
3 1.5 0 3 Kilometers
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community


Catchment
Watercourse
Selected NFM
Lower Priority
BUFFER STRIP
CONTOUR PLOUGH
FLOODPLAIN RECONNECTION
LWD
RUNOFF ATTENUATION FEATURE
TREE PLANT
WET WOOD
N
3
1.5
0
3 Kilometers
Midleton
Ballinacurra
Castlemartyr
Mogeely
Killeagh
Carrigtwohill
Dungourney
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community



Catchment
Watercourse
NFM Score
3.008360 - 3.515845
3.515846 - 3.684609
3.684610 - 3.802257
3.802258 - 3.921334
3.921335 - 4.155586
4.155587 - 4.365833
N
3 1.5 0 3 Kilometers
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community
Midleton
Dungourney
Mogeely
Castlemartyr
Killeagh
Carrigtwohill
Ballinacurra
Ladysbridge

Appendix C

Natural Water Retention Measures – National Context

C1 OPW Status Update (2nd Feb 2021)

As the lead State body for the coordination and implementation of Government policy on the management of flood risk in Ireland, the OPW recognise that NWRM has a part to play in managing flood risk.

In May 2018 the Office of Public Works (OPW) published 29 Flood Risk Management Plans to address flood risk in Ireland. The Plans, which set out the whole of Government approach to managing flood risk, all have a specific measure regarding NWRM as follows:

'The OPW will work with the Environment Protection Agency, Local Authorities and other agencies during the project-level assessments of physical works and more broadly at a catchment-level to identify any measures, such as natural water retention measures (such as restoration of wetlands and woodlands), that can have benefits for Water Framework Directive, flood risk management and biodiversity objectives.'

The OPW are progressing with three actions to implement this measure; delivering Flood Relief Schemes, the NWRM Working Group, and Research and Pilot Studies.

Flood Relief Schemes

The OPW in partnership with the respective local authorities are currently progressing 57 of the 118 Floor Relief Schemes recommended in the Flood Risk Management Plans.

The first in a five stage process to deliver a flood relief scheme is to carry out scheme development and design, building upon the work already carried out in the National CFRAM Programme. During this phase, the scheme designers are required to carry out a NWRM feasibility assessment. This assessment will look at the feasibility of NWRM to form part of the flood relief scheme and also at the potential to achieve co-benefits.

The progression of these flood relief schemes is an opportunity for the implementation of NWRM to complement traditional engineering solutions.

NWRM Working Group

A NWRM Working Group was established to advise the River Basin Management Plan (RBMP) National Technical Implementing Group (NTIG) on proposals for including NWRM as part of a broader suite of mitigation measures that could contribute to the achievement of environmental objectives set out in the second RBMP.

In September 2020 the NWRM Working Group set out their recommendations in a report for the NTIG. The recommendations were as follows:

- At the national level, utilise and/or enhance existing policies and measures to achieve maximum multiple benefits from NWRM within existing funding mechanisms.

- At the catchment level, conduct a pilot study to assess the feasibility and cost-benefit of implementing NWRM at the catchment scale and recommend strategies for their implementation. Use the learnings gained as a springboard to roll out implementation nationally.
- At the local level, prepare a simple best practice guidance document for Ireland to help community groups undertake local scale
- Consideration should be given to development of a land use strategy or plan for Ireland that takes account of the principles of slowing the flow to achieve multiple environmental benefits. Similarly, any national river restoration guidance for Ireland should include the findings of this study.
- Provide input to any future national drainage policy to incorporate NWRM as an integral part of the overall strategy.
- A multiagency group under the NTIG to continue a forum to co-ordinate efforts for implementation of NWRM.
- Rebrand NWRM in Ireland as: "Nature Based Catchment Management Solutions".

Research and Pilot Studies

The principal NWRM research being undertaken in Ireland is the SLOWWATERS project: 'A Strategic Look at Natural Water Retention Measures'. This four-year duration research, which is being carried out under the EPA Research programmes Water Research Call 2018, commenced in February 2019 and has a budget of €508,000. The research will assess the benefits of Natural Water Retention Measures for agricultural catchments in Ireland. The project outputs will provide recommendations for the management of specific catchment types relevant to the Irish environment by quantifying the magnitude of NWRM required to reduce flood peaks. Two demonstration sites in Cork and Wexford will show how to design, build and instrument NWRM. It is envisioned that the demonstration sites will be visited by numerous stakeholder groups to evaluate the practicalities of uptake of NWRM on Irish farms.

The research is being led by Professor Mary Bourke of Trinity College Dublin and the team includes authors of the Environment Agencies (UK) Working with Natural Processes - Evidence Directory from Newcastle University and The James Hutton Institute in Scotland as well as participants from University College Cork.

Research is also being carried out to assess the potential for NWRM in forested catchments in Ireland. The OPW through the Irish Research Council Enterprise Partnership Scheme are co-funding PhD research, titled 'The ecosystem services of Ireland's forests for flood protection and water quality'. The aim of the proposed project is to test the potential role of specifically-designed NWRM within conifer plantations to attenuate the flux of water, sediment and soluble pollutants to receiving waters and thereby reduce the flood risk and environmental impact of forestry operations to sensitive catchments. This research commenced in March 2019 and will use GIS-based mapping techniques, hydrological modelling, and full-scale field demonstration sites.

Through these three actions the NWRM measure in our Flood Risk Management Plans will be substantially complete and will provide us with an additional suite of measures to compliment traditional engineering solutions to flood risk management while also achieving multiple-benefits in other sectors.