Physical restoration options to address morphology and flood pressures on the River Dee - a pilot study

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PHYSICAL RESTORATION OPTIONS TO ADDRESS MORPHOLOGY AND FLOOD PRESSURES ON THE RIVER DEE – A PILOT STUDY

FINAL REPORT

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Executive summary

The River Dee has been identified by SEPA as a pilot catchment for developing an approach to integrated, catchment scale management of water resources. The aim of the project was to identify achievable restoration and management options that provide the multiple benefits of moving water bodies in the Dee catchment to 'good ecological status' (under the Water Framework Directive (WFD)) and enhancing natural flood management (NFM), while also considering additional benefits (e.g., improved biodiversity, enhanced condition of specific habitats, socio-economic factors etc.).

Options to address morphological degradation and to enhance natural flood management were initially assessed separately. Options were then combined to determine where opportunities for multiple benefits exist and these were assessed using a multi-criteria analysis (MCA). A subsequent, expert judgement-based assessment taking into account option costs and constraints was used to provide a final ranking of options.

Morphological restoration opportunities were identified on twelve water bodies within the Dee catchment that were either already classified as being at less than good ecological status for morphology, or where additional field-based assessment of pressures indicated that status for morphology should be below good. Restoration opportunities were assessed based on the degree of morphological pressure removed. This was determined from SEPA's morphological impact assessment system (MImAS). In addition, options were assessed to determine whether they would improve water body WFD status for morphology. A geomorphological assessment was carried out on three water bodies using field-based data. It is recommended that in future studies of this nature this type of assessment be carried out across the catchment so that data on geomorphic process can be used within the assessment of restoration options.

Assessment of NFM potential was carried out for two broad categories of measures: floodplain reconnection measures and out-of-floodplain land use and drainage re-naturalisation measures. Assessment for both types was carried out using HEC-HMS, a catchment scale hydrological model, which was used to determine the change in flow peak at the water body outlet resulting from each modelled measure. Floodplain reconnection measures were modelled in 14 water bodies where current floodplain disconnection as a result of embankment and high impact realignment pressures was identified. The greatest flow peak reduction was found to occur as a result of floodplain reconnection in the Dee main stem downstream of Peterculter, Tarland Burn and Gormack Burn. Out-of-floodplain measures were assessed in 30 water bodies that represented flow generation areas. Alteration of the BFIHOST model parameter was used as an analogue for re-naturalisation of land use and drainage patterns. The parameter was altered based on the proportion of land in the catchment that was classed as 'impacted' and therefore had potential for re-naturalisation. The greatest reduction in flow peak resulting from this measure was in Brodiach/Ord Burn water body. However, the model indicated that none of the out-of-floodplain measures had a significant effect on flow peak at the Dee catchment outlet.

Engagement with stakeholders was an important aspect of the project and occurred throughout the assessment process. A stakeholder workshop was held towards the beginning of the project in order to gather information concerning previous and planned restoration activities within specific areas of the catchment. Following the MCA process, a list of ranked options was sent to stakeholders, giving them the opportunity to provide any further relevant information on the options. This information was used within the final assessment of options.

MCA was used as a semi-quantitative means of assessing the multiple benefits associated with undertaking restoration actions at each identified location. Each option was assigned scores relating to its benefits in terms of morphological restoration and NFM, as well as additional environmental and socio-economic criteria. These were used to provide an overall ranking of options. A subsequent assessment taking into account costs, constraints, additional benefits and opportunities for funding and collaborative work, as well as the MCA score, was used to provide a final ranking of options. The options ranked highest are the most favourable on the balance of overall benefit and practicality of implementation, providing a starting point for determining which options to take forward. However, options that do not fall into the top ten should not be completely ruled out.

The highest ranked option was re-meandering and removal of embankments on the Dee main stem near Milltimber, which would increase water body status from bad to moderate, as well as providing potential reduction in flood risk in the Aberdeen PVA. Other favourable options included embankment removal and/or re-meandering on reaches of the Tarland Burn, the Leuchar Burn and the Gormack Burn, as well as several other tributary water bodies.

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Glossary

Term	Definition
Avulsion	The process whereby a river abandons its old channel and forms a new one.
BFIHOST	Base Flow Index derived for the HOST soil classification. This is a measure of the rate of runoff response.
Capacity used	A measure used in MImAS to describe the degree of morphological pressure within a section of river. This is expressed as the percentage of a river's capacity to absorb morphological pressures that is being used.
Croy	A jetty-like feature jutting out from a river bank.
Descriptor	A value or category used to describe a particular characteristic of an object (such as a catchment or a river). In the Flood Estimation Handbook descriptors refer to various statistical values relating to hydrology and soil type that are used as a means of describing a catchment's characteristics.
Diffuse pollution	Pollution entering a river which originates from across a wide area (e.g. runoff from an arable field), rather than from a single point.
DPLBAR	Mean of distances between each node on IHDTM grid and the catchment outlet (km). Characterises catchment size and configuration.
DPSBAR	Mean of all the inter-nodal slops for the catchment: characterises the overall steepness.
Dynamic behaviour	The rate at which geomorphic processes in a river occur and cause changes to the river's shape.
Flood peak attenuation	The slowing of flood waters so that they arrive at the catchment outlet over a longer period of time, resulting in a lower, and possibly later, flood peak.
Geodatabase	A method of storing electronic spatial data within a Geographic Information System (GIS).
Geomorphic process	An effect of the interaction between flow and sediment in a river, such as bank erosion or alluvial bar formation.
Geomorphic process intensity	A measure used in this study to express the rates at which sediment supply, transport and storage occur within a river reach.
Geomorphic process regime	The relative balance of the supply of sediment to the system and the capacity of the river to transport that supply. This dictates the river's shape and the types of process that occur.
Geomorphic/ geomorphology/ morphological	In relation to land forms (specifically rivers in the context of this report) and the processes that shape them.
Hazard rating	In MImAS, a value assigned to a pressure according to its predicted degree of impact. The predicted degree of impact depends on channel subtypology as well as pressure type.
HOST	Hydrology Of Soil Types - classification of soil types based on their hydrological response (i.e. what happens to rain when it falls onto them).
Incision	Downwards erosion of a river.

Term	Definition
Manning's *n*	A value used to describe roughness of a surface, in order to determine how water would flow over it (normally within a model)
MImAS	Morphological Impact Assessment System. A tool developed by SEPA to quantify the impact of morphological pressures within water bodies.
NFM	Natural flood management – techniques to manage flood risk by working with, or enhancing, natural processes in a catchment.
Poaching	Ground disturbance by livestock .
Pressure	An anthropogenic feature or activity that is adversely affecting the geomorphic processes in a river.
PROPWET	Proportion of time when soils were defined as wet (moisture deficit equal to, or below, 6mm) during 1961-90.
Reach type	A description of the dominant channel characteristics and processes in a section of river. Also referred to in MImAS as 'subtypology'.
Reference state	Used in river restoration to define how a particular river would look and behave if un-impacted. This is the ultimate target for restoration and can be used as a benchmark against which restoration measures are assessed.
Return period	A statistically calculated estimate of the likely interval at which a given event will occur. In the case of this report the event is a flood of a certain magnitude.
SAAR	Average annual rainfall in the standard period (1961-90) (mm). (SAAR4170 is from 1941 to 1970)
Specific stream power	The rate of energy dissipation against the bed and banks of a river per unit of downstream length and width. This indicates the potential ability of the river to erode and transport sediment.
SPRHOST	Standard Percentage Runoff (%) associated with each HOST soil class – a measure of the runoff response
Sub-catchment outlet	The downstream-most point on a river within a sub-catchment, i.e. just upstream of the point where it flows into another river.
Subtypology	See Reach type.
Supply-limited	In relation to sediment transport, where the capacity of the river to transport sediment is higher than the rate of sediment supply to the river. The rate of sediment transport is limited by the rate of supply.
Transport-limited	In relation to sediment transport, where the capacity of the river to transport sediment is lower than the rate of sediment supply to the river. The rate of sediment transport is limited by the river's transport capacity.
URBEXT1990	Extent of urban and suburban land cover in 1990 (fraction).
Water body	A spatial unit of river around which WFD assessment is based.
WFD	Water Framework Directive. A European directive which provides the main framework for water management in Europe.

1. INTRODUCTION

Recent years have seen increasing recognition of the need for an integrated, catchment scale approach to management of water resources in Scotland and more widely. The principle of integrated catchment management underpins two important pieces of European legislation, the Water Framework Directive (WFD) and the Floods Directive. These two directives share much of the same structure and are designed to work in conjunction with one another. This project seeks to identify opportunities to integrate the delivery of water environment restoration measures at the catchment scale in order to meet the requirements of both directives: restoring impacted hydromorphology to meet the objectives of WFD and achieving natural flood management (NFM) to meet the objectives of the Floods Directive. In addition, the identification of opportunities where potential exists to achieve further benefits to meet wider environmental and social policy drivers is a key element of the project.

The River Dee has been identified by SEPA as a pilot catchment for developing a strategy to identify and implement restoration options that combine morphological restoration and NFM. The Dee is one of four such pilot catchments across Scotland, and the work reported here is the first phase of a project that will run until 2016. The Dee catchment was the subject of a scoping study which identified and appraised morphological restoration options (SNIFFER, 2011). The work reported here develops the findings of the earlier project.

There are a number of water bodies in the Dee catchment that are failing to meet the WFD requirement of ‘good ecological status’ for reasons relating to morphological pressures. In addition there are six areas that have been identified as at potential flood risk (Potentially Vulnerable Areas, PVAs). This presents a good opportunity to identify measures within the catchment that can simultaneously address the issues of flooding and morphological degradation. Such targets have to be planned and delivered at a whole catchment scale and in an integrated manner, since the physical character of the river system (from headwaters to mouth and including the channel, floodplain and hillslopes) is intrinsically inter-related with flood processes and characteristics. This notion is perhaps especially relevant for rivers that have been significantly impacted by human activity, which often results in exacerbated flooding issues in focussed (and often developed) areas. Early and continued engagement with stakeholders is also a very important component in the successful delivery of these types of measures.

This project seeks to develop approaches to integrated catchment management by identifying management and restoration measures that can deliver multiple benefits at the catchment scale. The fundamental aim of the project is therefore to identify achievable restoration and management options that provide the multiple benefits of moving water bodies in the Dee catchment to ‘good ecological status’ (under the WFD) and enhancing NFM, while also considering further additional benefits (e.g., improved biodiversity, enhanced condition of specific habitats, socio-economic factors etc). The consideration of NFM benefits supports the obligation of the Scottish Environment Protection Agency (SEPA) to assess potential for NFM in the preparation of flood risk management plans (under Section 20 of the Flood Risk Management (Scotland) Act 2009). A third piece of European legislation, the Habitats Directive (Natura), is also implicitly linked to the overall aims of the project through its requirement for the protection of key species and their supporting habitats. The River Dee is classified as an SAC (Special Area of Conservation) under this legislation because it supports populations of otter, Atlantic salmon and freshwater pearl mussel.

In many cases the requirement for multiple benefits is likely to result in potentially conflicting factors and the project aims to develop a methodological approach that can quantify the net benefits of a combined optimal management plan for the river system at the catchment scale.

1.1 APPROACH

The project takes a whole river (catchment-scale) approach that considers the detrimental physical modifications to geomorphic and flood generation/ propagation (i.e., hydrologic) processes over a range of timescales. By linking this to strategic planning and working closely with stakeholders, we optimise the opportunity of both improving the quality of the water environment and reducing flood risk. In order to work effectively at the catchment scale, the project uses a spatially nested methodology whereby data synthesis and interpretation at broad scales are used to inform and direct the assessment of process at relatively high spatial resolutions. In turn this ensures that individual interventions at specific sites are designed so that they will be integrated into the long-term, catchment-wide vision for the river. These 'process based' interventions will contribute to more natural system physical (geomorphic) and flood (hydrologic) functioning and ensure that the benefits can be maintained with minimal intervention over the long term. A further fundamental principle is that re-establishing the natural physical functioning of the river will also result in the improvement in the extent and quality of the ecology/ habitat which, in turn, will lead to a general improvement in the condition of its biota.

The initial stages of the study are concerned with developing a detailed understanding of the geomorphic and hydrological processes operating within the River Dee system and on understanding the artificial impacts to physical process and on the natural flood regime. This information is used as the basis for development of morphological restoration and NFM options. These options are then integrated and assessed in terms of their various benefits and costs, using multi-criteria analysis (MCA) to form prioritised multi-benefit restoration options. The restoration options put forward are of sufficient detail to allow an objective prioritisation of potential restoration opportunities across the catchment. However, in-depth stakeholder engagement with land owners and land managers will be critical in order to understand the feasibility of the potential options and willingness to proceed to implementation. The best environmental options may be the least acceptable from a social or economic perspective due to the impact on existing land use. This extensive engagement with land owners/ managers comprises phase 2 of the overall project. Furthermore, detailed, site specific assessments will be required before any projects could proceed to implementation.

The objectives of the work are as follows:

- Compile existing spatial geomorphic data, including data on morphological pressures, into a GIS and supplement with further field surveys to provide a catchment-scale dataset.
- Analyse the nature and distribution of morphological pressures and identify opportunities for morphological restoration.
- Develop an understanding of system-scale geomorphic process and use this information to help determine physically appropriate morphological restoration options.
- Use hydrological modelling to identify potential locations for NFM within the Dee catchment and to quantify the potential reduction in flooding severity from undertaking NFM measures at these locations.

- Integrate the morphological restoration and NFM opportunities to produce a series of potential interventions and assess these in terms of benefits to morphology, NFM and additional factors.
- Provide a series of prioritised restoration options across the Dee catchment that will help restore water bodies to good ecological status and also deliver a quantifiable reduction in downstream flood risk through NFM.
- Use stakeholder engagement throughout the process to ensure that options take into account their needs and views, and to determine where opportunities to work with stakeholders to carry out restoration work may exist.

A flow chart mapping out the various stages in the project is shown in Figure 1.1.

This report sets out the approach taken and the information generated at each step of the study, to show how the resulting restoration options were arrived at. The geomorphic/ WFD component of the assessment is described in Section 2, the hydrological component in Section 3 and stakeholder engagement in Section 4. Section 5 describes the multi-criteria analysis process used to score and rank options according to their multiple benefits. Section 6 describes the final prioritisation of options. A summary of the recommended actions, together with methodological recommendations, is provided in Section 7.

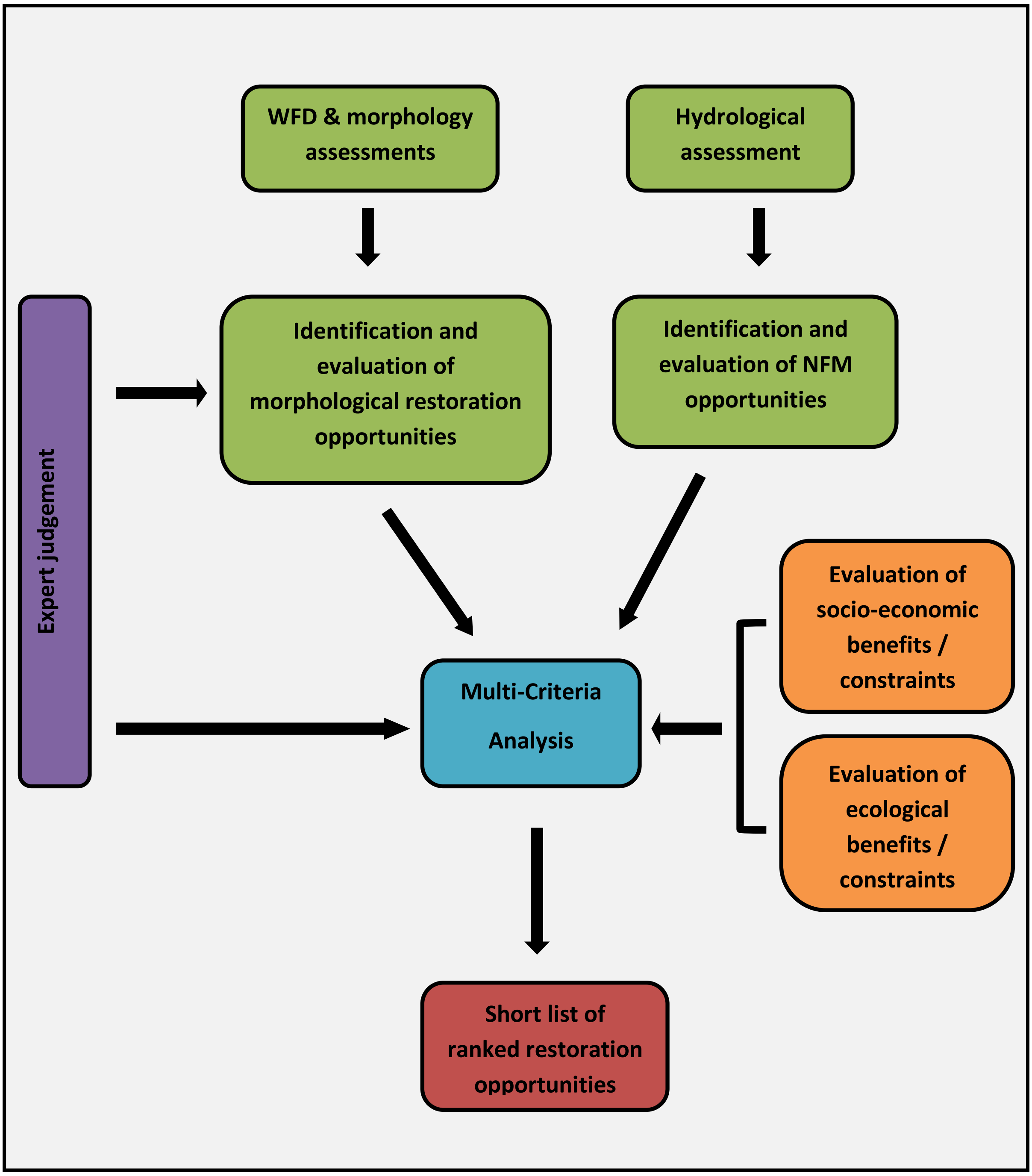


Figure 1.1 Flow chart illustrating the stages of work in the project

1.2 CATCHMENT OVERVIEW

This section provides an overview of the catchment characteristics, derived from a brief literature and data review, to give context to the following sections of the report.

The River Dee is one of the major rivers in eastern Scotland. Located in the Grampian region it drains an area of around 2200 km^2. The river flows approximately 130 km, rising in the southern Cairngorm mountains and northern Grampian region and joins the North Sea at Aberdeen (Figure 1.2). The main tributaries of the river include the Feugh, Muick, Clunie, Gairn, Lui, Tanar and Culter system. The Dee is a predominantly rural catchment. The main land uses are agriculture and commercial forestry. Agriculture consists of rough grazing in the upland areas with a transition to intensive arable and livestock agriculture in lowland areas of the catchment. Correspondingly, land-cover in the upper parts of the catchment is predominantly heather moor, with associated sporting estates, with arable and improved grassland found in the lower catchment (CEH, 2013). The Dee flows through the city of Aberdeen and its conurbation. Other significant urban areas within the catchment include the towns of Peterculter, Banchory, Ballater and Braemar. Surface geology in the catchment consists of till, glacial sand and gravel (BGS, 2013). The underlying geology consists of psammites/pelites (metamorphic rocks) with igneous intrusions.

At the lowest gauging station in the catchment (Dee at Park) the mean flow between 1982 and 2012 was 47.2 $m^3 s^{-1}$ (CEH, 2013). The Dee has a history of flooding at several locations along its length. PVAs have been designated on the Dee main stem at Ballater, Banchory and Aberdeen. In addition, there are PVAs on several tributaries: the Culter Burn at Peterculter, the Brodiach/Ord Burn and the Beltie Burn (which merges with the PVA at Banchory) (indicated on Figure 1.3).

The River Dee is renowned for its salmon fishery, which is of worldwide importance and is an important source of income and jobs in the area. Most of the river is designated as a Special Area of Conservation (SAC) for its Atlantic salmon, freshwater pearl mussel and otter habitat.

Pressures on the morphology and physical processes of rivers within the Dee catchment are most evident in the eastern (downstream) half of the catchment. All 29 water bodies upstream of Aboyne are at good or high status for morphology. In contrast, nine of the 24 water bodies downstream of Aboyne are at less than good status for morphology (according to SEPA's predicted morphology status, July 2011, Figure 1.3). A further three water bodies downstream of Aboyne were found to be at less than good status following field surveys carried out as part of this study.

The most prolific types of morphological pressure in the lower part of the catchment are embankments and realignment, most of which have been constructed in relation to agricultural activity and land drainage. Morphological pressures related to fishery enhancements (including croys, bank protection and weirs) are also present in the catchment. SNIFFER (2011) found that the lower reaches of the Dee main stem were frequently impacted by engineering pressures (such as bank protection, croys and embankments). Realignment, associated with agricultural activities or urban development was found to be most extensive on the Dee downstream of Peterculter as well as on the Bo Burn. The effects of commercial forestry present a further morphological pressure in parts of the catchment. Morphological pressures in the Dee catchment are discussed in detail in Section 2.

1.3 PREVIOUS SCOPING STUDY

A SEPA and SNH commissioned scoping study of physical restoration options for diffuse pollution priority catchments has already been undertaken on the River Dee (SNIFFER, 2011). This was an entirely desk-based study which aimed to identify opportunities and appropriate measures to improve the morphological quality of the study area, to assist in meeting WFD and Habitats Directive requirements. The report considered the entire Dee main stem, along with two tributary water bodies: the Bo Burn and the Burn of Corrichie.

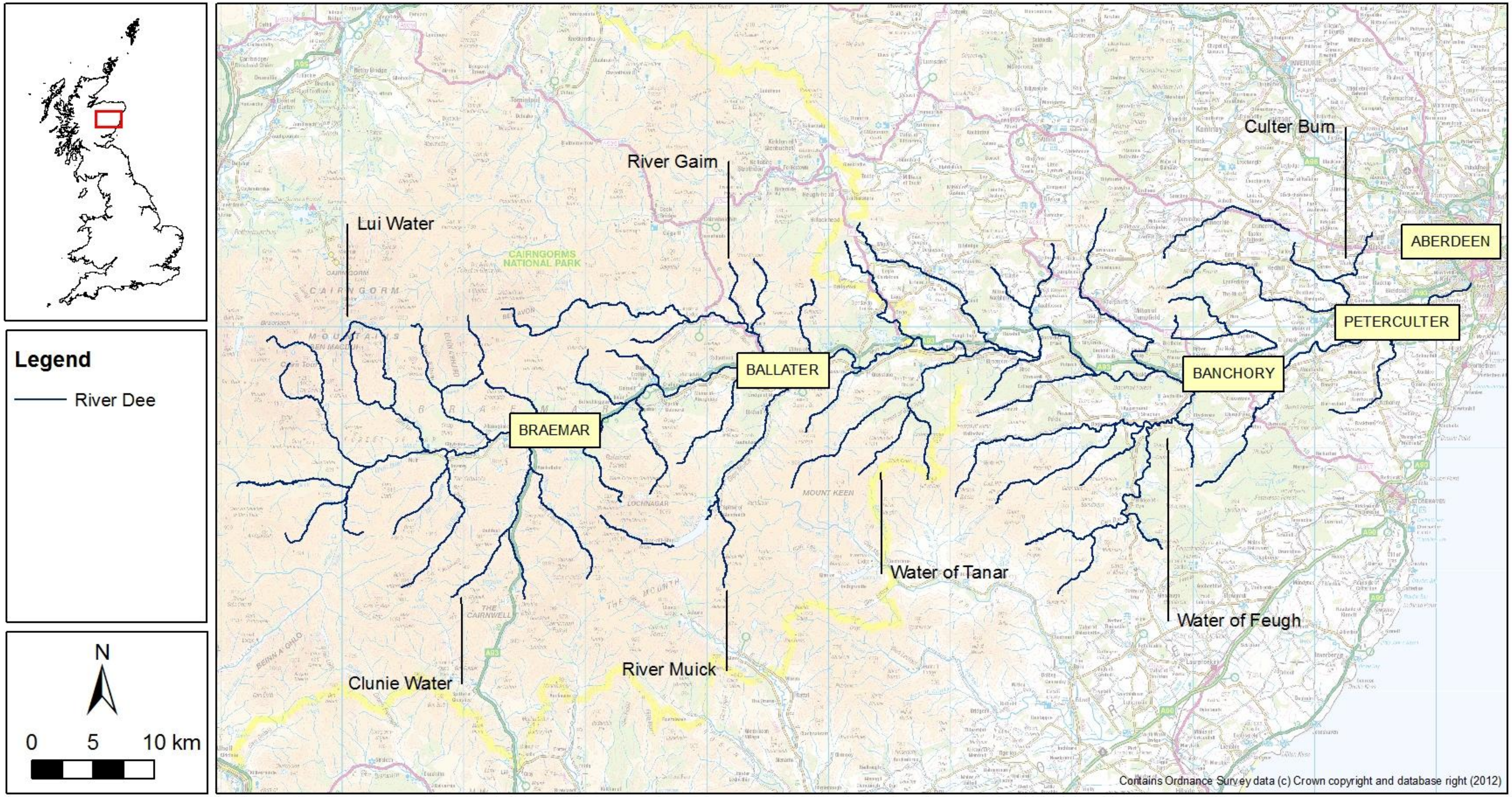
Restoration measures were identified which aimed to restore natural processes where possible, including full river or floodplain restoration, and to reduce diffuse pollution inputs from land management activities. These were assessed using a multi-criteria analysis approach to come up with a list of favoured options. The main options were:

- diffuse pollution management on the Dee main stem and the Burn of Corrichie, targeted at freshwater pearl mussel habitat;
- removal of bank protection, embankments and croys on Dee main stem, or replacement with softer alternatives;
- Set back embankments on Dee – Peterculter to tidal limit;
- Re-meandering of the Bo Burn;
- Allow natural recovery of the Bo Burn where possible.

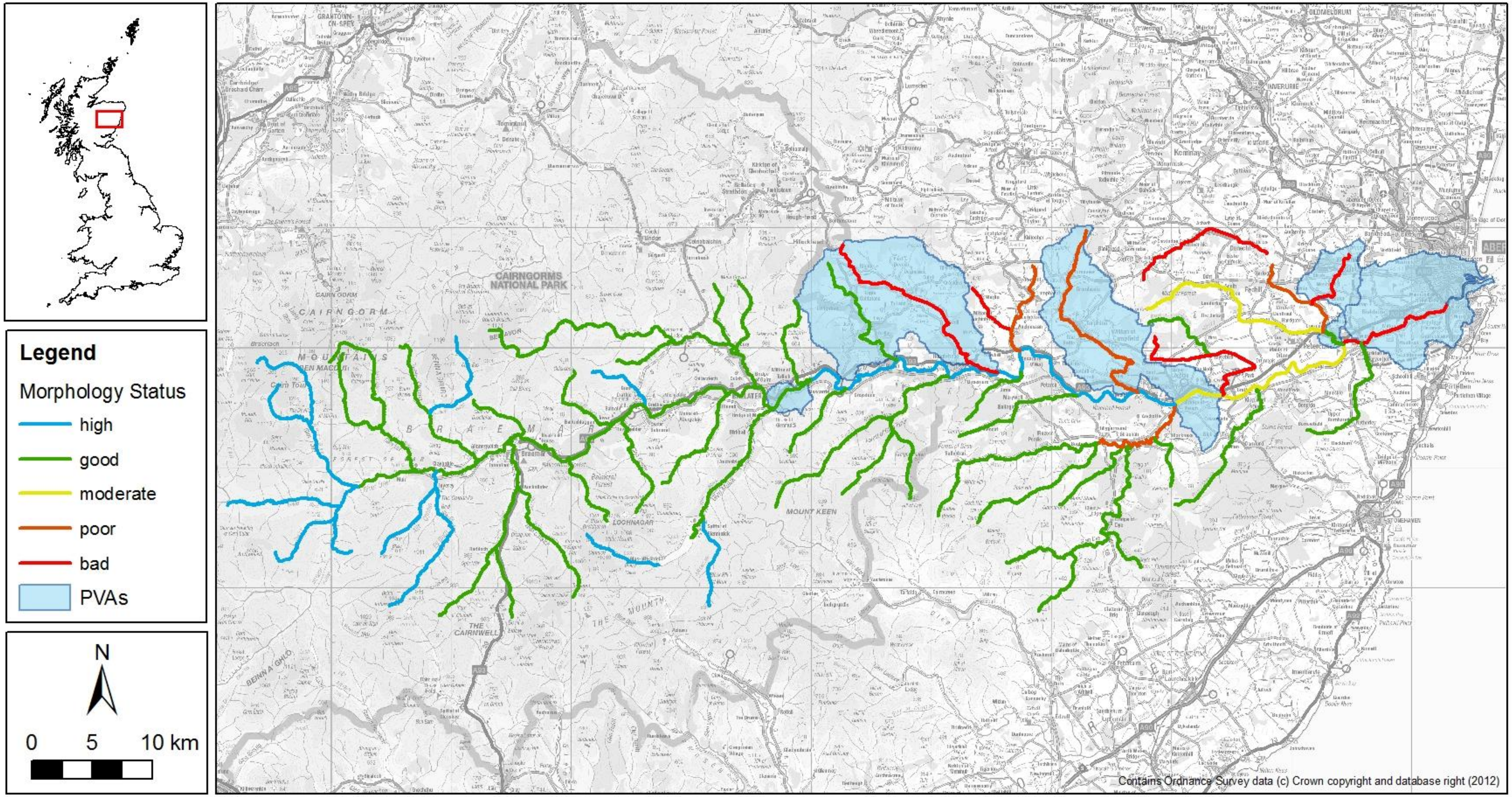
Consultation of the restoration options with the project Technical Advisory Group (TAG) and with selected external stakeholders led to the identification of a series of preferred options to take forward to development. The consultation, together with the multi-criteria analysis, indicated that favoured locations for implementing options were those towards the downstream part of the Dee main stem, together with the reaches of the Bo Burn to the north of Myrebird.

Prior to taking the recommended options forward to indicative design stage, it was recommended by SNIFFER (2011) that further consultation with the TAG to refine the multi-criteria scores might be necessary before finalising the chosen options. Consultation with land owners would also be needed prior to indicative design.

The current study represents a further stage in the identification of restoration options within the Dee catchment, which will build on the outputs of the SNIFFER work. The current study will add to the number of options because it considers a larger number of water bodies, including all tributaries that are at less than good status for morphology, compared with the SNIFFER study. The current study also incorporates the additional factor of benefit to NFM, and therefore requires a revised multi-criteria analysis. Following completion of this stage of the work, the outputs, incorporating the outputs from the SNIFFER work, will be taken forward to the detailed design and delivery phases of the project.



Notes:	cbec eco engineering	*River Dee Restoration* **Dee catchment overview**		
		Project No. U13-1008	Created By: GK	**Figure 1.2**



Notes:

River Dee Restoration

Dee PVAs and WFD morphology status (2011 classification)

Project No. U13-1008	Created By: GK	**Figure 1.3**

2. GEOMORPHIC ASSESSMENT

This section covers the element of the project that addresses the morphological pressures within the Dee catchment. The initial sub-sections below describe the geomorphic characterisation and quantification of morphological pressures within the Dee. This leads on to identification of restoration opportunities and assessment of their potential benefits in terms of improvements to WFD status for morphology.

2.1 WATER BODY SCREENING

At the outset of the project twelve water bodies within the Dee catchment were selected on which to focus the assessment (Table 2.1). These were water bodies that were either failing to meet good ecological status for morphology, or were currently at good status but thought to have significant morphological pressures that were not reflected in the current classification. Field surveys were subsequently undertaken on the three selected water bodies at low confidence good status (River Dee – Banchory to Peterculter, Water of Feugh – lower catchment, Beltie Burn), in order to identify any further morphological pressures. Desk-based assessment using SEPA's existing morphological pressures data was used in the nine water bodies already at less than good status.

Table 2.1 Summary of water bodies selected for assessment in the Dee catchment

Water body Name	Water body ID	Length (km)	Predicted morphology status (July 2011 classification)	Assessment method
River Dee - Peterculter to tidal limit	23315	10.4	Bad	Desk-based study
River Dee - Banchory to Peterculter	23316	17.8	Good	Field survey
Gormack Burn	23320	18.9	Moderate	Desk-based study
Leuchar Burn	23321	9.0	Poor	Desk-based study
Brodiach Burn / Ord Burn	23322	6.5	Bad	Desk-based study
Kinnernie Burn	23323	13.5	Bad	Desk-based study
Bo Burn	23324	16.3	Bad	Desk-based study
Water of Feugh - lower catchment	23326	10.9	Good	Field survey
Beltie Burn	23333	21.9	Good	Field survey
Dess Burn / Lumphanan Burn	23336	9.3	Poor	Desk-based study
Dess Burn - upper stretch	23337	5.2	Bad	Desk-based study
Tarland Burn	23338	20.6	Bad	Desk-based study

2.2 FIELD BASED SURVEY

Field walkover surveys were undertaken on the Dee from Banchory to Peterculter, the Beltie Burn and the lower Feugh.

The field walkover surveys consisted of two components. The first component was a survey of morphological pressures using SEPA's MImAS (Morphological Impact Assessment System) methodology. The position and extent of every pressure impacting on morphology was recorded using a hand held GPS, along with information about the pressure type and characteristics. This information was subsequently entered into SEPA's morphological pressures database and was used to calculate the 'capacity used' by the pressure (described in Section 2.4). The types of pressure recorded are shown in Table 2.2. In addition, the MImAS methodology classifies the channel into one of five types (Table 2.3), based on the morphological processes and characteristics that would occur under unimpacted conditions. The channel type defines the degree of sensitivity to morphological pressures and is used when calculating the 'capacity used' of a pressure (as described in Section 2.4). A full description of the MImAS methodology can be found in SEPA (2010).

Table 2.2 Morphological pressures recorded as part of the MImAS survey

Category	Features
Bank modifications	Embankments; set back embankments; grey bank protection; green bank protection; bank reprofiling.
Sediment management	Sediment removal or addition; dredging.
Channel modifications	Realignment; flood bypass channels
In-stream structures	Flow deflectors, bed reinforcement and impoundments
River crossings	Bridge piers; culverts
Riparian vegetation	Vegetation structure (complex, simple, uniform and bare); Tree density (continuous/semi-continuous, scattered, none) (Note: coniferous plantation recorded as bare and none).

Table 2.3 Reach type classifications in MImAS

Reach type	Sub-typology class
Bedrock	A
Cascade	
Step-pool	B
Plane bed	
Plane-riffle	C
Wandering/braided	
Active meandering	D
Passive meandering	F

The second component of the field walkover survey was the collection of further geomorphic information using a fluvial audit type approach, based on the standard cbec fluvial audit methodology (Appendix A). Any feature that provided an indication of fluvial form or process was recorded using a hand held GPS to mark its location and extent. The type of feature and any associated attributes were recorded. Types of feature recorded are shown in Table 2.4. The recording of channel engineering features was omitted from this component of the survey to avoid duplicating the MImAS component. Reach type was recorded in both the MImAS (Table 2.3) and cbec fluvial audit (Table 2.4) components of the surveys because of the different classification schemes used. It was felt that the two schemes were complementary and that both provided useful information, so reach type was classified under both schemes. Reach type descriptors from both classification schemes are therefore used in the descriptions of water body characteristics that follow.

Table 2.4 Features recorded in the fluvial audit component of the field surveys

Type of feature	Attributes recorded
Bank erosion	Start and end point; severity (low/moderate/high); mean height of feature (m); sediment type; bank affected
Sediment deposition	Start and end point; type of bar feature (point/lateral/medial/transverse), vegetation presence (none/semi-vegetated/vegetated), mean width of feature (m); bank affected (if relevant)
Poaching and stock pressure	Start and end point
Tributaries	Size (minor/moderate/major); evidence of sediment supply; bank affected
Reach type	Cascade; step-pool; plane bed; pool-riffle; slow glide

2.3 WATER BODY CHARACTERISTICS AND PRESSURES

A summary of the main geomorphic characteristics and pressures in each of the surveyed water bodies is provided in Table 2.5, with corresponding photographs in Table 2.6. More detailed analyses of the pressures and the geomorphic response of the system are undertaken in Sections 2.4 and 2.5. Maps indicating the geomorphic features recorded on the three surveyed water bodies in the fluvial audit component of the survey and the main pressures on each of the selected water bodies (based on SEPA's existing data in the water bodies where additional field surveys were not undertaken) are shown in Appendix B.

Across the study reaches as a whole, reach type was predominantly plane-riffle or active meandering, with the upper sections of headwater water bodies typically characterised by steeper step-pool or plane bed sections. The Bo Burn also contains significant passive meandering reaches.

Embankments were found in most studied water bodies and are a particularly prevalent pressure on the Dee main stem downstream of Peterculter, as well as on the Tarland and Beltie Burns and the upper section of the lower Feugh water body. Hard bank protection was also widespread in several water bodies, including the Dee between Banchory and Peterculter, the Beltie Burn, and the Dess/Lumphanan Burn. A number of croys exist on the Dee between Banchory and Peterculter and on the lower Feugh, relating to fishery enhancements. Realignment was a very widespread pressure within all of the study water bodies except for the lower Feugh and the Dee main stem between Banchory and Peterculter. This is likely to have a significant impact on sediment erosion, transport and storage processes in these channels and on their ability to interact laterally with their floodplains.

Weirs were present on a number of water bodies, with particularly large numbers on the Beltie Burn, lower Feugh and the Leuchar Burn. Four large impoundments (2 m or higher) are recorded in the morphological pressures database. Two are found towards the upstream of the Leuchar Burn water body, one towards the downstream extent of the Bo Burn and one on the Kinnernie Burn. All are impounding a significant body of standing water. However, further information about their impact on morphology was not included in the database.

Livestock poaching on channel banks was recorded as a pressure in the three surveyed water bodies, but is not included as a type of pressure within MImAS, so data on poaching pressures were not available for the other study water bodies. Figure B3 (Appendix B) indicates that on the three water bodies surveyed livestock poaching pressures are restricted to three reaches on the Beltie Burn, and two reaches on the upper Feugh. Livestock poaching of banks was observed to alter the bank structure, reduce vegetation cover and increase potential for bank erosion and fine sediment input (Figure 2.1). It is therefore a significant geomorphic pressure within the reaches impacted, but is of relatively low significance across the water bodies as a whole. This information is included in Appendix B as it is relevant for the diffuse pollution priority catchment work ongoing in the catchment. SEPA are also keen for this information to be collected routinely in all future projects of this nature, with the information to be utilised for the SEPA land unit when carrying out diffuse pollution priority catchment activities.

Figure 2.1 Effects of livestock poaching on channel banks - A: Upper reaches of lower Feugh; B: lower reaches of the Beltie Burn.

Table 2.5 Summary of geomorphic characteristics and pressures in each surveyed water body

Water body	Reach type	Sedimentary characteristics	Morphological pressures	Vegetation and land use
River Dee – Banchory to Peterculter	Pool-riffle reach type with active meandering sections. Some small reaches with lateral confinement on one bank.	Bank erosion and alluvial bar deposition throughout reach, but becoming increasingly prevalent downstream.	Bank reinforcement and croys, associated with fishery management extremely prevalent throughout the water body, impacting on sediment recruitment and lateral geomorphic process.	Banks almost entirely managed for fishery. Variable vegetation cover, with vegetation complexity in many reaches reduced through mowing.
Beltie Burn	Steep step-pool section in upper reaches, becoming increasingly plane bed and then pool-riffle/slow glide downstream, with a steeper pool-riffle/plane bed section at the downstream extent.	Generally low levels of bank erosion and deposition, with a slight reduction in the downstream half of the water body (possibly associated with straightening).	Realignment/straightening in central part of water body, with associated embankments, causing overdeepening and preventing interaction with floodplain. Hard bank protection found throughout much of water body, except the upper-most reaches, further impacting on sediment recruitment and lateral geomorphic process.	Low levels of vegetation complexity upstream, where upland moorland/rough pasture land use. Increasing levels of tree cover downstream, except for central, straightened section where low riparian vegetation diversity associated with arable land use.
Water of Feugh – lower catchment	Upper half dominated by pool-riffle reach type. Becomes steeper downstream of Belts of Cullonach, with bedrock control towards Dee confluence.	Frequent bar deposition in the upstream half, much reduced in confined downstream section. Bank erosion rates generally low, at least partly due to artificial bank protection measures.	Extensive embankments in upper half of water body preventing lateral interaction with floodplain. Bank protection, croys and a series of weirs in downstream half (associated with fishery) altering both lateral and longitudinal connectivity of sediment recruitment and transport.	Little or no impact to riparian vegetation throughout water body. Land use typically pasture in upper half. Increase in woodland land use downstream, with fishery in lower-central section of water body.

Table 2.6 Images illustrating characteristics of surveyed water bodies

River Dee – Banchory to Peteculter	
	
Mown and protected bank in centre of water body	Croy and bank protection upstream Peterculter
Beltie Burn	
	
Upstream of Torphins	Straightened section downstream Torphins
Water of Feugh – lower catchment	
	
Upper section	Bank protection and weir in fishery section

2.4 MIMAS PRESSURES DATA ANALYSIS

The MImAS data collected in the field surveys were entered into a GIS geodatabase. These data were then appended to the database containing the existing SEPA morphological pressures data for the nine water bodies in which field surveys were not undertaken. The MImAS scoring system (as described in SEPA, 2010, and the Scotland River Basin District Directions 2009, Scottish Government) was then applied. This assigns each recorded pressure a constant, known as a hazard rating, which is dependent on the type of pressure and the reach type in which it is located. The rationale behind this approach is the assumption that different reach types have differing levels of sensitivity to a given pressure. The hazard rating is multiplied by the pressure length and divided by the length of the water body to calculate the 'capacity' of the water body that is used up by the pressure. The total 'capacity used' within a water body (i.e. the sum of the capacity used by each of the pressures within the water body) is used to define its ecological status under the WFD in terms of morphological pressure.

Very long, continuous pressures may breach what is known as the 'Single Activity Limit' (SAL). This is a maximum specified pressure length; any pressures exceeding this would automatically result in the water body being downgraded from good status for morphology. The length depends on the pressure type and the channel type. Three SAL breaches were found on the Dee water bodies investigated and are discussed below.

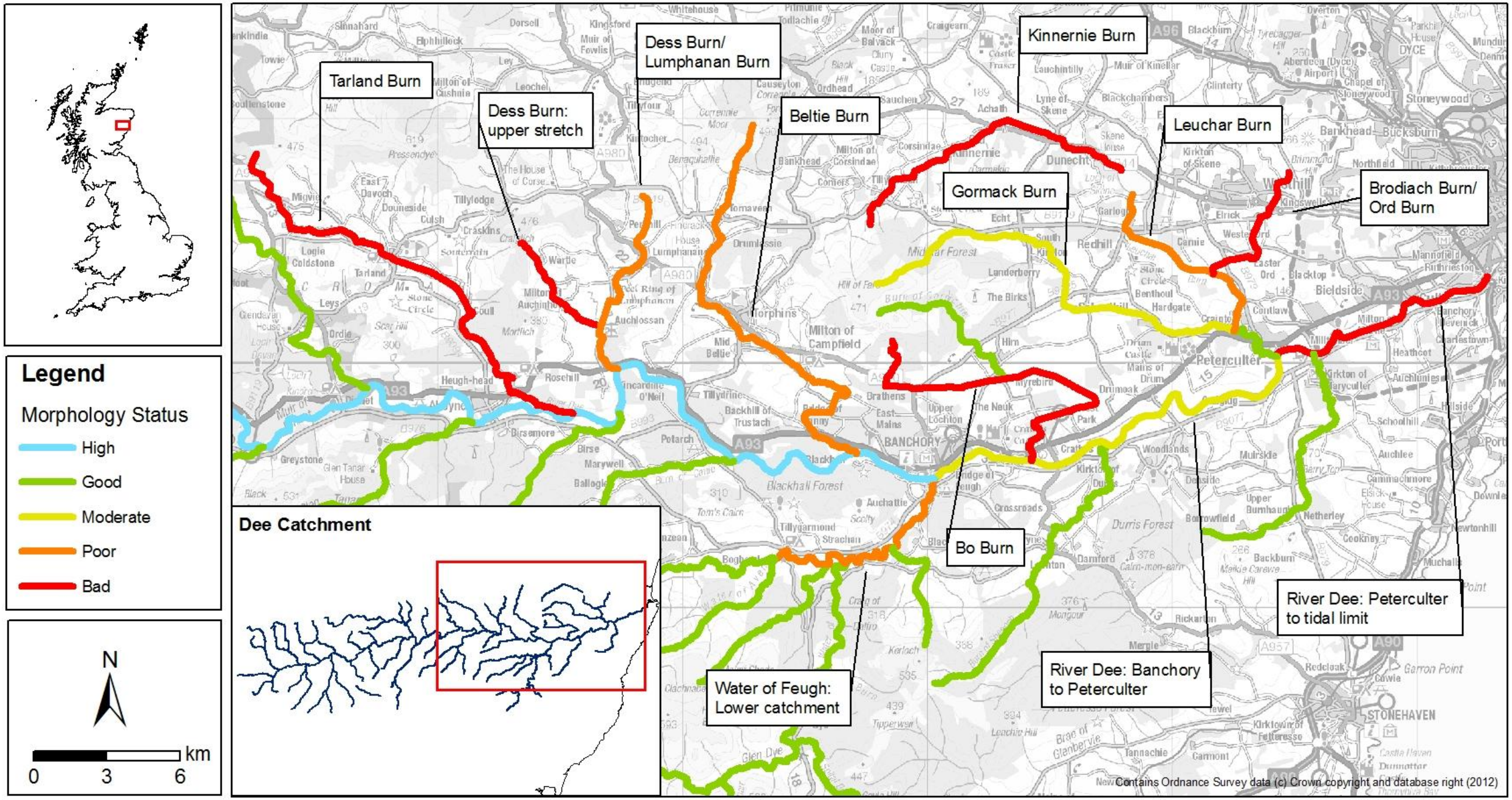
2.4.1 Analysis of water body WFD status for morphology

The results of the MImAS analysis were used to calculate the capacity used for each of the three surveyed water bodies. These values were compared with SEPA's existing desk-based estimates of capacity used (Table 2.7). The field-based scores showed a greater capacity used and resulted in a WFD status class downgrade in all water bodies (indicated in Table 2.7). Given the greater confidence associated with the field-based results, they were taken to be a better reflection of water body condition than the July 2011 scores. As such, the revised capacity used values were taken forward and used in all subsequent analyses in this report. It is recommended that SEPA ensure that subsequent water body classification is updated based on these data. The status class for each water body included in the assessment, with the status classes for the surveyed water bodies taken from the field survey results and the remainder taken from the SEPA 2011 assessment, is shown on Figure 2.2.

Table 2.7 Comparison of existing and revised 'capacity used' in surveyed water bodies

Water body		July 2011 classification		cbec June 2013 field-based classification	
ID	Name	Capacity used	Predicted morphology status	Capacity used	Predicted morphology status
23316	Dee - Banchory to Peterculter	14.02	Good	32.9	Moderate
23326	Water of Feugh - lower catchment	13.09	Good	59.3	Poor
23333	Beltie Burn	18.23	Good	64.3	Poor

The SAL breaches identified included a 2393 m length of high impact realignment on the water body Dee – Peterculter to tidal limit; a 3318 m length of high impact realignment on the Leuchar Burn; and a 4980 m length of high impact realignment on the Tarland Burn. These pressures alone would prevent the respective water bodies achieving good status for morphology, even if water body capacity used was reduced below the required limit.



Notes: Beltie Burn, Water of Feugh and Dee – Banchory to Peterculter based on field surveys carried out as part of this study. Other water bodies based on existing data.

River Dee Restoration

Lower Dee WFD status for morphology (study water bodies labelled)

Project No. U13-1008 | Created By: GK | **Figure 2.2**

2.5 ANALYSIS OF MORPHOLOGICAL RESTORATION OPTIONS

2.5.1 General approach

The initial list of restoration options to address WFD morphological pressures was developed based on analysis of the pressures using the MImAS methodology. Given that the MImAS total ‘capacity used’ is used to define the ecological status of a water body under the WFD (in terms of morphological pressure), using MImAS as a basis for assessing and prioritising restoration options provides a straightforward approach in terms of the definition of their degree of improvement to WFD-related criteria.

2.5.2 Delineation of management reaches

The MImAS analysis of the morphological pressures database was used to evaluate the capacity used by each individual pressure in each water body under consideration. Each individual pressure provides an opportunity for restoration and release of capacity. However, a total of 823 pressures, not including riparian vegetation loss, were recorded in the database for these water bodies. Many of these features represent sub-divisions of the same pressure (e.g. an embankment), or one of several discrete pressure types present in the same reach (e.g. a series of croys). Treating each pressure as a separate restoration option would result in a large number of fragmented and spatially discontinuous options that would be difficult to assess further and inefficient to implement.

Instead, spatial analysis of pressures and their locations relative to each other was used to develop restoration options that included multiple adjacent or coinciding pressures at a spatial scale deemed manageable for restoration work. Logical groupings and divisions of pressures were used to form a series of management reaches. These were reaches in which pressures contributing significantly to water body capacity used were situated, and are therefore locations where opportunities for improvement to water body status exist. The advantages of using this approach are:

- The focus on locations where significant improvements can be attained (often by addressing multiple pressures)
- Very long pressures can be broken into lengths that may be more appropriate for restoration.

The delineation of management reaches was carried out based on expert judgement, informed by the spatial analysis of pressure locations. The locations of pressures, as recorded in SEPA’s morphological pressures database, were displayed within a GIS of the Dee. Visual analysis was used to identify spatial groupings of pressures within each water body. This information was combined with visual assessments of maps, aerial imagery and geomorphic data for each water body to locate other features which may be important in delineating management reaches (e.g. locations of farms and settlements or changes to geomorphic reach types). The information was used to determine lengths of channel within which a series of pressures could be addressed through restoration. These management reaches were typically between one and four kilometres in length. 56 reaches were identified in total. Details of management reaches are provided in Appendix C. It is envisaged that the boundaries of those management reaches taken forward to further appraisal might be altered in light of more detailed analysis, but the current divisions provide a useful basis for initial assessment of options.

Management reaches had already been defined on the Dee main stem from Peterculter to tidal limit and on the Bo Burn as part of the previous study (SNIFFER, 2011). The reaches defined as part of the current study on these water bodies largely coincide with the SNIFFER reaches, but differences in scope and approach between the two projects meant that in some cases reach boundaries were adjusted. The SNIFFER project used fluvial audit data to define reach boundaries. These data were not available for all water bodies covered in the current study and could not, therefore, be used to form a consistent approach to reach boundary delineation. Given that one of the main objectives of the current study is to identify opportunities to improve water body status for morphology, locations of pressures as defined in MImAS were used as a means of delineating reach boundaries consistently across the catchment. The reaches defined on the Bo Burn in the SNIFFER study were typically shorter than the length considered to be appropriate to the current study (given the large extent of the current study, management reaches of 1 to 4 km in length were considered appropriate for the initial assessment of options). Management reaches defined on the Bo Burn therefore consist of several merged SNIFFER reaches.

2.5.3 Evaluation of restoration opportunities

Within each of the 56 management reaches, the capacity that could be released by addressing each of the various types of pressure was calculated. The total capacity that could be released by addressing all the pressures included was also calculated (certain types of pressure were excluded from the analysis, as described below). These calculations are shown in Appendix C. In addition to complete restoration of high impact realignment (HIR) and complete removal of embankments, the options of changing high impact realignment to low impact realignment (LIR) and setting back embankments were also considered. These options would release less capacity, but the option may be more compatible with existing land use (therefore more acceptable to land managers) and may also be associated with a lower cost of implementation.

Some rules were developed to ensure consistency and as a first order screening to prevent unmanageable numbers of options:

- Reaches were only included where there was the opportunity to release more than 2% capacity.
- Riparian vegetation loss was generally very insignificant in terms of its capacity used and was therefore only included as an option for those reaches where it released more than 1% capacity.
- Set back embankments have a very low hazard rating within MImAS and therefore contribute very little to capacity used. As such, their removal was not considered in any of the options. Indeed, as mentioned above, they are proposed as a potential restoration option to replace embankments situated closer to the channel banks.
- Bridges also typically have a very low hazard rating. Large bridges with a higher hazard rating are likely to be carrying important infrastructure. Therefore removal of bridges was also omitted from any option.

The types of pressure that were considered are summarised in Table 2.8.

Table 2.8 Types of measure considered within the management options and the number of reaches addressed by each

Restoration option	Number of reaches addressed
Remove embankments	30
Set-back embankments	30
Mitigate high impact realignment	26
Alter high impact realignment to low impact realignment	26
Remove bank protection	17
Remove croys	21
Remove weirs	7
Remove culverts	2
Restore vegetation	15

For each management reach identified there were a number of sub-options, reflecting the multiple pressures typically found in each reach. Options ranged from addressing one or more of the types of pressure to full restoration. The table in Appendix C indicates the capacity released from addressing each type of pressure, therefore showing the measures that will have the greatest benefit to WFD status. The information in Appendix C can also be used to determine the capacity released by implementing combinations of options or sub-options. Information about each individual pressure and its capacity used is available in GIS format through SEPA's morphological pressures database, to enable the end user to interrogate the data and determine how the pressures within each reach make up the overall capacity used.

Options were assessed based on the capacity released and whether or not they released sufficient capacity to improve the WFD ecological status class of the water body. These are coloured in the options spreadsheet (Appendix C) to indicate the reaches where opportunity to improve water body status exists. Options are differentiated according to whether status is improved to 'good', by two status classes (but not to good), or by one status class (but not to good). Water bodies that are currently close to the upper boundary of their status class therefore provide more restoration opportunities that will lead to a WFD classification upgrade. The options that lead to the removal of a single activity limit are also indicated.

Owing to the fact that a water body's capacity used is calculated as a function of its length, water body length is significant in determining the capacity released by a given restoration action. The water bodies addressed here vary in length between 5 and 22 km. A given pressure would use up more capacity in a shorter water body than a longer one, meaning that mitigation of this pressure would result in a greater improvement to WFD status in the shorter water body. Shorter water bodies are, therefore, likely to provide more restoration opportunities that will lead to a WFD classification upgrade. It should be recognised that, because of this bias, restoration options in longer water bodies are likely to have greater benefit to local morphology than is accounted for by their scores. A factor was included in the final assessment of options (Section 6) to mitigate for this bias. However, it is recommended that in future iterations of this process, the bias is accounted for at an earlier stage (e.g. within the initial ranking of morphological restoration options or the MCA)

Table 2.9 summarises the top ten morphological restoration options, based on whether the option results in an improvement in WFD status class and on the overall capacity released. Options in Leuchar Burn reach 2 and Dess/Lumphanan Burn reach 1 both resulted in improvement of water body status from poor to good, making them highly favourable. Both would involve re-meandering of a straightened watercourse (i.e. restoring from HIR), together with embankment removal, to allow reconnection with the floodplain. Restoration of riparian vegetation would further add to the quality of the reach.

Despite only releasing 7.9% capacity, the option to remove embankments, bank protection and croys and restore vegetation on the main Dee at Park House scored highly because it would result in improvement of water body status to good.

The option that released the greatest capacity was removal of embankments, mitigation of high and low impact realignment, removal of bank protection and restoration of vegetation on the Dee between Milltimber and Ardoe House Hotel. This would involve large-scale channel realignment and result in an increase in floodplain inundation during floods. However, the option would improve water body status by two classes to moderate and would result in a significant improvement to the geomorphic functioning of this reach of the Dee.

All of the highest scoring options listed in Table 2.9, except for the option on Kinnernie Burn, involve removal of embankments, while all but the option at Park House involve mitigation of high impact realignment. They are all, therefore, likely to require modification of the channel margins, as well as the active channel itself.

In some water bodies there are a number of measures, or combinations of measures, that lead to the same WFD benefit. The subsequent multi-criteria analysis of options (Section 5), which considers NFM potential and other important factors (e.g., biodiversity, socio-economic factors etc.), will be used to objectively differentiate between these measures. Following the MCA, stakeholder feedback and other information regarding the practicalities of implementation will be used as a final level of assessment of option favourability.

Table 2.9 Summary of top ten morphological restoration options

Water body	Reach no.	Reach location	Reach length (m)	Options	Change to water body status class	Capacity released (%)
Leuchar Burn	2	Garlogie to Broadwater	3360	Remove embankments; mitigate HIR; remove BP; restore vegetation	Poor → good	49.9
Dess Burn / Lumphanan Burn	1	Auchlossan to Muir of Dess	2070	Remove embankments; mitigate HIR; remove BP; restore vegetation	Poor → good	45.5
Dee - Banchory to Peterculter	4	Park House	2160	Remove embankments; remove BP; remove croys; restore vegetation	Moderate → good	7.9
Dee - Peterculter to tidal limit	3	Milltimber to Ardoe House Hotel	3950	Remove embankments; mitigate HIR; mitigate LIR; remove BP; restore vegetation	Bad → moderate	94.4
Dess Burn - upper	1	Downstream Mill Farm	1600	Remove embankments; mitigate HIR; restore vegetation	Bad → moderate	66.4
Brodiach Burn / Ord Burn	1	Downstream Easter Ord Farm	2290	Remove embankments; mitigate HIR; mitigate LIR; restore vegetation	Bad → moderate	52.6
Gormack Burn	2	Milton of Cullerlie to Blackhall	3380	Remove embankments; mitigate HIR; restore vegetation	Bad → poor	33.3
Kinnernie Burn	2	A944 Bridge to Dunecht	3290	Mitigate HIR; remove BP; restore vegetation	Bad → poor	32.0
Brodiach Burn / Ord Burn	2	B9119 Bridge to Easter Ord Farm	2200	Remove embankments; mitigate HIR; remove BP; restore vegetation	Bad → poor	31.3
Beltie Burn	2	Torphins to Milton of Campfield	3200	Remove embankments; mitigate HIR; remove BP	Poor → moderate	31.0

2.6 GEOMORPHIC ASSESSMENT OF RESTORATION OPPORTUNITIES

Improvement to the WFD status for morphology in the Dee water bodies, the ultimate aim of this exercise, is measured by changes to the MImAS capacity used score. The evaluation of restoration opportunities in the Dee water bodies was, therefore, based purely on the removal of morphological pressures as characterised by the MImAS methodology. However, because MImAS is designed to characterise large areas relatively quickly, there are necessarily some simplifications and associated limitations to the methodology, in particular, the lack of explicit incorporation of quantitative data on geomorphic process.

An assessment of geomorphic process at the system scale is considered an extremely important component of any restoration strategy. A quantitative understanding of system scale variation in dominant process and degree of dynamic behaviour provides an indication of the likely sensitivity of the system to change (e.g. during a large-scale flood event), as well as the sensitivity of the system to modifications. This is important for assessing the likely impacts of engineering and land use pressures, as well as determining the geomorphic response to restoration interventions and allowing restoration options to be developed that are appropriate within the context of the entire system, as well as at the reach scale.

Given that fluvial audit data were collected in the field for only three of the water bodies under consideration, a full geomorphic process assessment at the catchment scale was not possible as part of this study. Geomorphic assessment within the three water bodies surveyed was carried out and is reported in Appendix D. However, the reduced spatial coverage of this assessment limits its use for analysis of system scale geomorphic process and assessment of restoration options in light of this. It is recommended a geomorphic assessment of this type is carried out across the catchment more widely, prior to detailed design and implementation of any of the options identified here. This would involve a fluvial audit-type approach. Existing data could be used where available, with field surveys where necessary, in order to build up an understanding of the sediment supply, transport and storage processes within the catchment, or sub-catchment, of interest.

In future iterations of the MCA process, it is recommended that the geomorphological dynamics are used to determine the suitability of a measure, and that this process could be used as another part of the MCA to devise an overall ‘WFD Score’, comprised of (a) a score describing potential benefit for WFD objectives and (b) a score describing how effective the measure might be based on an understanding of geomorphological dynamics.

3. HYDROLOGICAL ASSESSMENT

The aim of the hydrological assessment of the Dee catchment was to identify locations where natural flood management measures could be implemented and to determine the likely effect of these measures on flood risk downstream. Natural flood management is a term used to describe the use of techniques that work with natural hydrological processes to manage runoff within the catchment and reduce the flooding pressure on vulnerable locations downstream. In many situations this may represent a more sustainable approach to flood management than traditional hard engineering approaches. NFM also has the potential to create additional benefits, such as improvements to water quality and riparian habitats. However, further research is necessary to determine the effectiveness of NFM measures in reducing flood risk (particularly through hydrodynamic modelling) at a range of spatial scales and flood magnitudes. Implementation of NFM presents a number of challenges and, as such, the development and testing of NFM techniques is ongoing.

Under Section 20 of the Flood Risk Management (Scotland) Act, SEPA have a duty to assess the potential for NFM measures to contribute to managing flood risk and to appraise NFM measures alongside conventional flood management techniques when developing flood risk management plans. SEPA recognises the overlap between its NFM obligations and its obligations for river and floodplain restoration under the WFD (SEPA, 2012). This section of the pilot study aims to develop and implement an approach for identifying NFM opportunities at the catchment scale, which can then be integrated with WFD objectives in order to assess the multiple benefits that arise.

3.1 APPROACH

Identification of opportunities for NFM within the Dee catchment was undertaken using HEC-HMS, a catchment scale hydrological model with simple, steady-state hydraulic routing that accounts for channel and floodplain geometry. This was used to investigate the potential for two broad types of NFM technique across the catchment. The first type was the modification of floodplains, or channels within floodplains, to allow for greater flood water storage within the catchment (referred to as 'floodplain measures' in the following sections). The second type was alteration of land use or vegetation across broader areas of the catchment in order to slow or reduce rates of runoff (referred to as 'out-of floodplain measures' in the following sections). It is recognised that floodplain measures will coincide with WFD-related morphological pressures and, ultimately, projects which benefit both will be prioritised. However, a catchment-scale approach to the assessment of potential flood risk benefit through NFM such as this must also consider out-of-floodplain measures in order to be fully representative.

3.2 FLOODPLAIN MEASURES

3.2.1 Initial water body screening

SEPA have already undertaken a screening exercise for NFM potential in the Dee catchment as part of their 'Section 20' obligations. This screening was conducted across the whole of Scotland based on remotely sensed data for a number of catchment physical characteristics and therefore represents the broad-scale potential for NFM measures. It does not take into account local factors, such as locations where embankments are currently causing floodplain disconnection.

In order provide a catchment-level assessment of NFM suitability, screening of water bodies suitable for implementation of floodplain NFM measures was undertaken based on a simple morphological appraisal. SEPA's morphology pressures database was used to identify potential floodplain reconnection opportunities. These were:

i) locations that currently have embankments;

ii) areas of high impact realignment.

High impact realignment was assumed to indicate an over-deepened and straightened channel and, therefore, potential for reconnection with the floodplain through realignment and bed aggradation (e.g., through increasing channel roughness). The initial screening identified 14 water bodies where there was potential for NFM implementation. These included twelve tributary water bodies and two water bodies on the Dee main stem (Figure 3.1). The water bodies within the Dee catchment that were selected for further analysis in relation to NFM generally coincide with those areas identified in the Section 20 screening as having potential for NFM. The potential impact of NFM measures within these water bodies was then assessed using the modelling approach employed.

3.2.2 Floodplain measures modelling approach

A hydrological model with simple steady state hydraulic routing accounting for channel and floodplain geometry was created for the entire Dee system using HEC-HMS. Input flows were created using hydrograph routing in a non-steady state within the Revitalised Flood Hydrograph model (ReFH, Wallingford Hydrosolutions) for the 10 and 100 year return periods using catchment descriptors taken from the FEH CD Rom v3 (Flood Estimation Handbook, Centre for Ecology and Hydrology). The hydrographs created were found to be similar to those recorded in the HiFlows UK dataset, thus providing a validation. The model was divided into reaches and sub reaches depending on the location of floodplain measures. The Muskinghum-Cunge approach was adopted and simple 8-point cross sections were created to represent the geometry of different reaches and sub reaches within the model depending on their size and adjacent floodplain measures. Land cover data was taken from LCM 2007 data set and was used to estimate the Manning's *n* value for the riparian and floodplain zones of the channel. The Manning's *n* value of the river channel was assumed to be 0.035 as suggested by existing literature (Chow, 1959) and expert judgement. Channel slope data was taken from the most recent SEPA slope dataset, which was based on GEORGE DEM (a combination of LiDAR and NEXTMap data). Positions of embankments were taken from SEPA's morphological pressures database.

The model was run under existing conditions to create a baseline against which potential floodplain reconnection measures could be assessed. The degree of 'benefit' gained from each floodplain reconnection measure (i.e., embankment removal, channel realignment, increasing channel roughness and increasing floodplain roughness) was assessed based on the change to peak flow, relative to the baseline scenario. All modelled scenarios were run for events representing the 10 year and 100 year return periods to assess how floodplain reconnection measures may affect flood events of different magnitudes. The point within the catchment at which change to peak flow as a result of floodplain reconnection measures was assessed (i.e. the 'compliance point') was at the outlet of the relevant water body. This enabled assessment of how the flow peak was altered at a local scale (especially relevant where the water body itself is a PVA), as well as how the contribution of the water body to PVAs further downstream in the catchment would be altered (PVAs are discussed in Section 1.2 and shown in Figure 1.3).

The 14 selected water bodies were broken down into sub-reaches, according to the spatial delineations of potential floodplain reconnection measures. These were based on locations of embankments and high impact realignment using SEPA's morphological pressures database as described in Section 2. Sub-reach boundaries were different to the sub-reach boundaries defined in the morphological assessment (Section 2) because they were determined by the locations of the specific morphological pressures outlined above in relation to floodplain extent (whereas morphological sub-reach boundaries were defined based on assessment of all pressures and logical extents for restoration implementation). Locations of sub-reaches are given in Appendix E and shown on Figure 3.1 and Figure 3.2. Sub-reaches which did not contain embankments or high impact realignment were excluded from further analysis, although remained within the model for routing purposes. For each water body, the reduction in peak discharge was assessed for the scenario of implementing floodplain reconnection measures throughout the sub-catchment and for scenarios of implementing floodplain reconnection measures in individual reaches within that water body. This provided an indication of the water bodies, and the sub-reaches within those water bodies, where floodplain reconnection measures were most effective.

3.2.3 Floodplain measures modelling results

Two parameters were used to indicate the flow attenuation associated with each floodplain reconnection scenario. The first was the absolute reduction in peak discharge at the sub-catchment outlet, which was taken to be an indication of the contribution of the floodplain reconnection measure to the reduction of flooding in PVAs further downstream in the catchment. The second value was the local proportional (percentage) reduction in peak discharge. This was taken to be an indication of the contribution of the floodplain reconnection measures to local flood peak reduction within a specific water body. These results are given in Appendix E. Flood peak changes associated with floodplain reconnection measures in individual sub-reaches are also shown in Figure 3.1 and Figure 3.2. The modelled changes to peak discharge associated with implementing measures in all sub-reaches of each water body are shown in Table 3.1.

It should be noted that the modelled values of discharge reduction are intended simply as a means of high level comparison between water bodies and reaches. The model used does not resolve local hydraulics in high resolution and, as such, the absolute output values are subject to a considerable degree of uncertainty. However, the relative values can be used to quantitatively prioritise the locations where the greatest potential for floodplain reconnection measures exists. It is recommended that, prior to the implementation of ground works, higher resolution hydrodynamic modelling is undertaken in order to more accurately understand the influence of an individual floodplain reconnection measure on flood peak attenuation.

Table 3.1 Flood peak reduction at each modelled water body outlet when all NFM measures implemented within that water body.

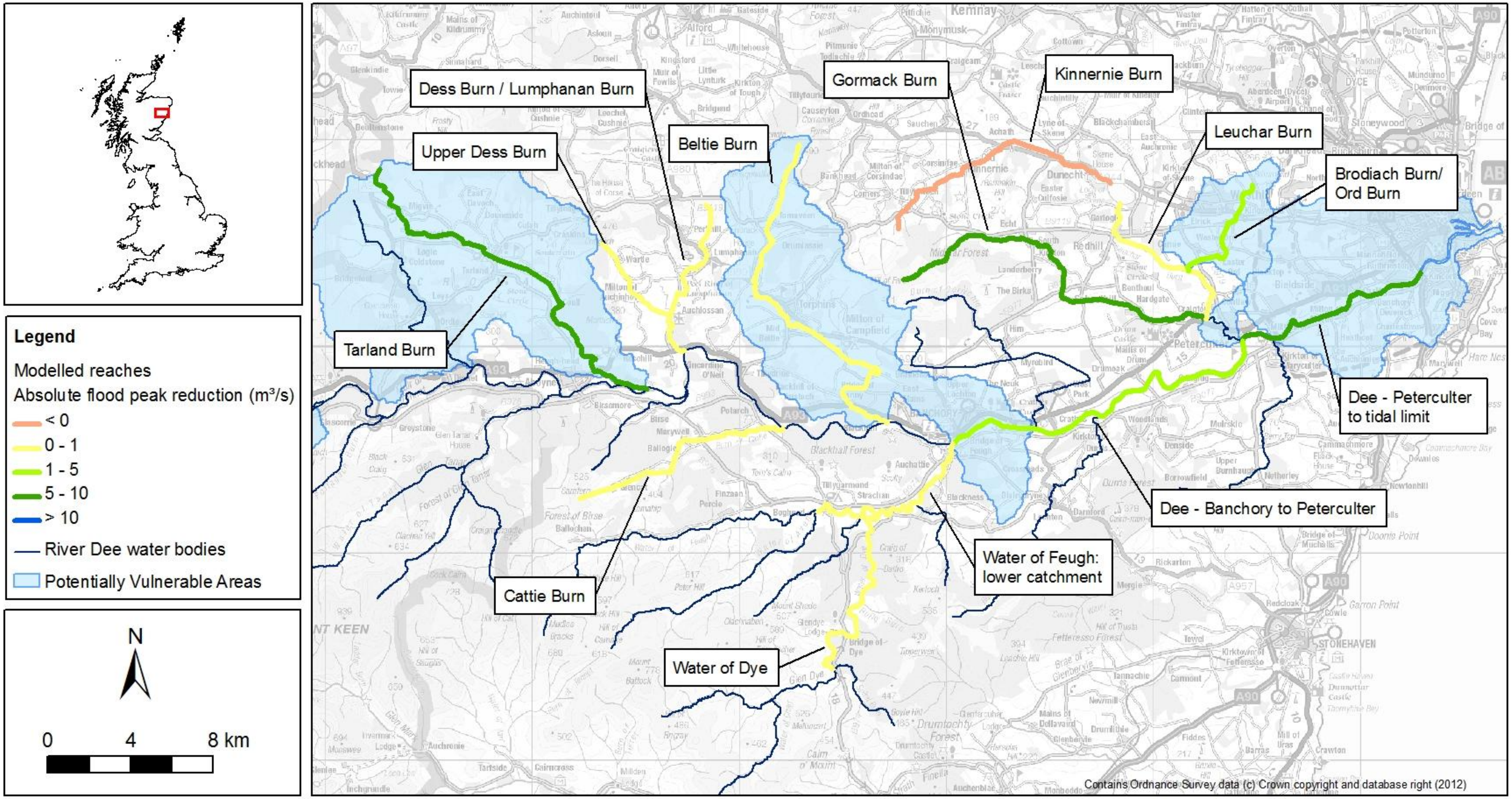
Water body ID	Water body name	Baseline scenario flood peak at outlet ($m^3 s^{-1}$)	Reduction to flood peak when all NFM measures in water body implemented	
			Absolute reduction ($m^3 s^{-1}$)	Percentage reduction
23315	River Dee - Peterculter to tidal limit	829.4	66.46	8.01
23316	River Dee - Banchory to Peterculter	806.6	9.64	1.20
23320	Gormack Burn	24.8	1.28	5.16
23321	Leuchar Burn	27.2	0.01	0.03
23322	Brodiach Burn / Ord Burn	8.6	0.15	1.75
23323	Kinnernie Burn	17.4	-0.02	-0.09
23324	Bo Burn	7.5	-0.61	-8.09
23326	Water of Feugh - lower catchment	180.5	1.25	0.69
23328	Water of Dye - lower catchment	84.5	0.15	0.18
23333	Beltie Burn	32.5	0.04	0.11
23334	Burn of Cattie	14.3	0.02	0.12
23336	Dess Burn / Lumphanan Burn	16.4	0.01	0.07
23337	Dess Burn - upper stretch	10.4	0.00	0.02
23338	Tarland Burn	25.3	1.35	5.33

The water body with by far the greatest absolute and proportional reduction in flood peak was the Dee main stem from Peterculter to the tidal limit. The large catchment area, and therefore, high absolute discharge regime of this water body partly explains the large absolute change (66.46 $m^3 s^{-1}$). The large proportional change reflects the extensive embankments and wide adjacent floodplain in parts of the water body, which provide considerable potential for flood water storage. Within the water body, implementation of floodplain reconnection measures in reach 5 had the greatest single effect on flood peak attenuation, with a 2.6 % change. This is a straightened and partially embanked reach with much potential floodplain storage. It is recognised that the proximity of this water body to the Aberdeen conurbation may result in land-use conflicts in relation to implementing floodplain reconnection measures. These issues are addressed in the final assessment of options (Section 6).

The River Dee – Banchory to Peterculter water body had the second highest absolute reduction in flood peak (9.64 $m^3 s^{-1}$), reflecting its large catchment area (and, therefore, discharge), but its floodplain NFM measures are less significant in terms of percentage reduction in flow. The Tarland and Gormack Burns had the second and third highest percentage reduction in flood peak (5.33 and 5.16 $m^3 s^{-1}$, respectively). In the Tarland Burn NFM measures in reach 7 were the most effective, while in the Gormack Burn reaches 5 and 6 were the most effective. In all cases these are straightened reaches with potential for re-meandering and floodplain reconnection.

Table 3.1 indicates that, in some cases, the model predicts that NFM measures will have the effect of increasing the flow peak (shown by a negative change). This is the case for the Kinnernie and Bo

Burns. The full results table in Appendix E further indicates a number of sub-reach scale measures on other water bodies that have the effect of increasing flood peaks. It is hypothesised that the mechanism behind these increases may be the synchronisation of hydrograph peaks. The NFM measures slow down the runoff that would normally form the early part of the hydrograph so that it reaches the water body outlet at the same time as the main flow peak. As noted above, the absolute values from the model output should be viewed cautiously, but the results suggest that floodplain NFM measures are unlikely to be effective in these reaches. Further and more detailed hydrodynamic modelling, in conjunction with analysis of existing flow data (where available), should be used to gain an additional understanding of any proposed works in these water bodies/ sub-reaches on flood peak propagation.

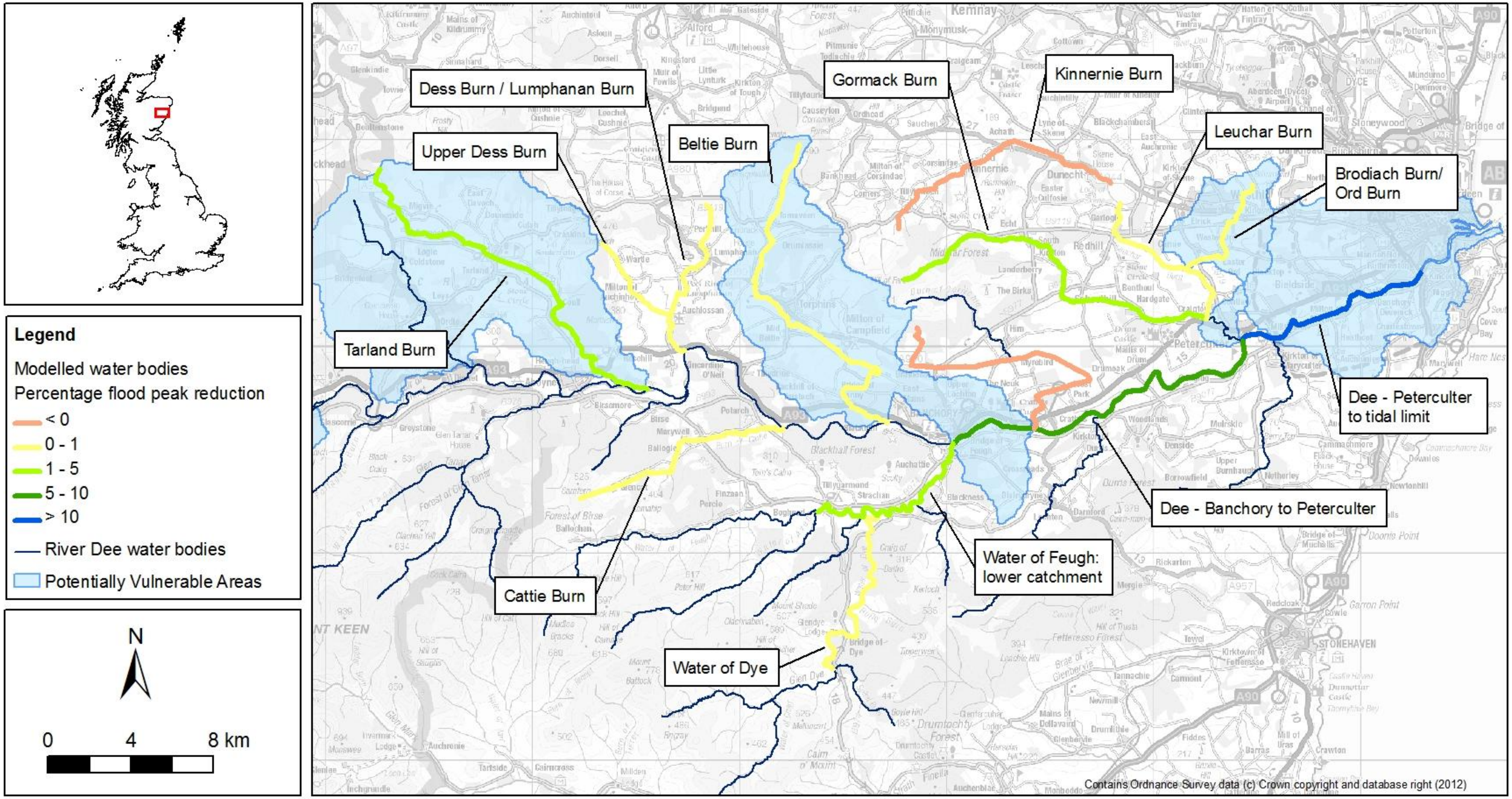


Notes:
Modelled absolute reduction in flow peak resulting from NFM implementation in individual reaches.

River Dee Restoration

Modelled absolute reduction in flood peak from NFM measures

Project No. U13-1008	Created By: CM	**Figure 3.1**



Notes:
Modelled percentage reduction in flow peak resulting from NFM implementation in individual reaches

River Dee Restoration

Modelled percentage reduction in flood peak from NFM measures

Project No. U13-1008	Created By: CM	**Figure 3.2**

3.2.4 Scoring of floodplain reconnection measures for NFM potential

The outputs of the hydrological model formed the basis upon which sub-reaches within water bodies were scored for their floodplain reconnection potential. This section describes how the relative and absolute values of flood peak reduction were combined to give an overall score for each reach.

Given the typically small influence of floodplain reconnection measures at the sub-reach scale on flow peak reduction, it is likely that, in order to realise significant NFM benefit, implementation of measures within multiple sub-reaches would be necessary. Owing to hydrological and hydraulic complexity within the sub-catchments, the effect of implementing floodplain NFM measures in multiple reaches is not simply the sum of the individual reach effects; in some cases the cumulative effect at the scale of the respective water body is greater and in other cases it is smaller. It would be impractical to model the effects of NFM implementation in every possible combination of sub-reaches, owing to the very large number of combinations (i.e., many thousand). A simpler approach was taken to account for the cumulative effect of implementing measures in multiple reaches. The predicted changes in flow peak resulting from implementation of measures in individual reaches in a water body were adjusted so that their sum was equal to the modelled flow change when measures were implemented in all reaches in the water body (as illustrated in Figure 3.3). Further detail is given in Appendix F.

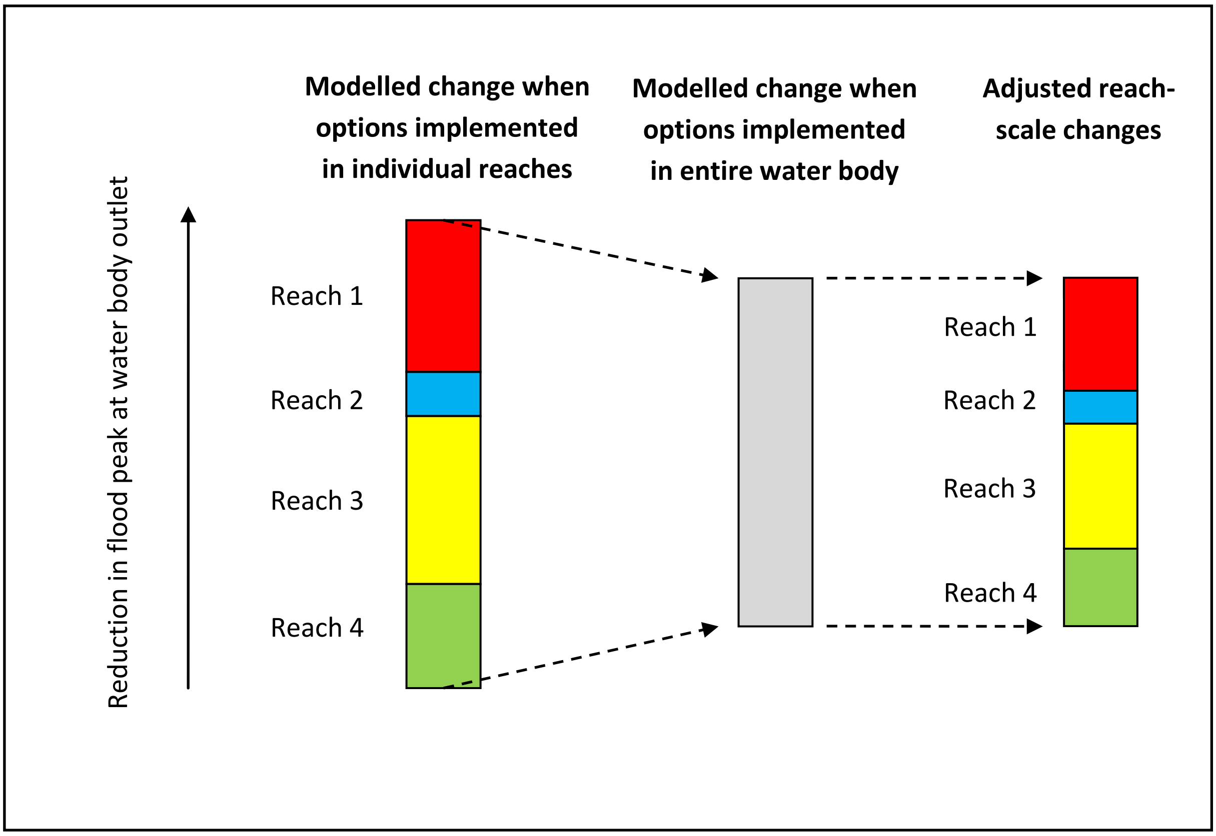


Figure 3.3 Diagram to illustrate how reach-scale outputs were adjusted based on water body-scale outputs to generate the adjusted reach-scale benefit values.

It should be recognised when interpreting the results that they do not fully account for the hydrological changes predicted when floodplain NFM measures are implemented in multiple reaches. The adjustments described above and in Appendix F were designed as a simple means of accounting, within the necessary high level assessment undertaken here, for the fact that measures may be implemented in multiple sub-reaches. It is recommended that further, more detailed modelling of candidate floodplain reconnection measures be undertaken should measures be planned in multiple sub-reaches, in order to understand the hydrological interaction of adjacent sub-reaches and the effect of this on the efficacy of floodplain reconnection measures.

Any adjusted scores that were negative (i.e. indicating an increase in the flood peak discharge) were replaced with a value of zero (i.e. no change in flood peak discharge). The hydrological modelling is intended as a means of comparing NFM potential but cannot be relied upon to determine with any degree of certainty that a given measure will have the effect of increasing flood peaks. Negative values were removed to reflect this.

The adjusted values of absolute and proportional changes to flood peak magnitude represented the scores used to rank the sub-reaches in terms of their floodplain reconnection potential. Weightings were applied to the scores to reflect the likely impact on PVAs. Given that PVAs are the locations targeted for flood risk mitigation, scores for floodplain reconnection measures in sub-reaches and water bodies that are either in a PVA, or directly flow into a PVA were given a higher weighting than those with only an indirect impact.

Weightings were applied as follows: The absolute peak reduction score was given a weighting of two if the water body flowed directly into a PVA. This was to reflect the reduced contribution of upstream inputs to the flood peak in the PVA. The relative reduction score was given a weighting of two if the water body was within a PVA, in order to reflect the local-scale reduction in flood risk. All other sub-reaches were given a weighting of one. The two scores were standardised to make them directly comparable and then added to give the overall floodplain reconnection benefit score. These scores are provided in Appendix E, while Table 3.2 summarises the top ten floodplain reconnection reaches in order of benefit to NFM.

Table 3.2 Reaches with the top ten scores for floodplain reconnection

Water body ID	Water body name	Reach no.	Floodplain reconnection score
23315	River Dee - Peterculter to tidal limit	5	72.02
23338	Tarland Burn	7	53.47
23315	River Dee - Peterculter to tidal limit	6	38.41
23315	River Dee - Peterculter to tidal limit	1	32.94
23315	River Dee - Peterculter to tidal limit	9	29.65
23316	River Dee - Banchory to Peterculter	5	28.98
23315	River Dee - Peterculter to tidal limit	8	27.90
23315	River Dee - Peterculter to tidal limit	7	19.85
23320	Gormack Burn	6	16.27
23320	Gormack Burn	5	15.14

3.3 OUT-OF-FLOODPLAIN MEASURES

Alteration of land use type and management within a catchment is known to influence hydrograph characteristics through the effects of land/ vegetation cover and drainage characteristics on volumes and rates of runoff. It is generally considered that a less intensive land use with a greater degree of vegetation cover and more natural drainage characteristics (e.g. without artificial drains or compacted soil) will slow or reduce runoff rates. Water bodies that represented significant flow generation areas within the Dee catchment were identified. These were taken to be all headwater water bodies. The effect of re-naturalising land cover and drainage patterns on hydrograph characteristics was modelled in each of these sub-catchments in order to identify the sub-catchments where this had the greatest potential effect on reducing flood peaks at a series of compliance points downstream.

3.3.1 Out-of-floodplain measures modelling approach

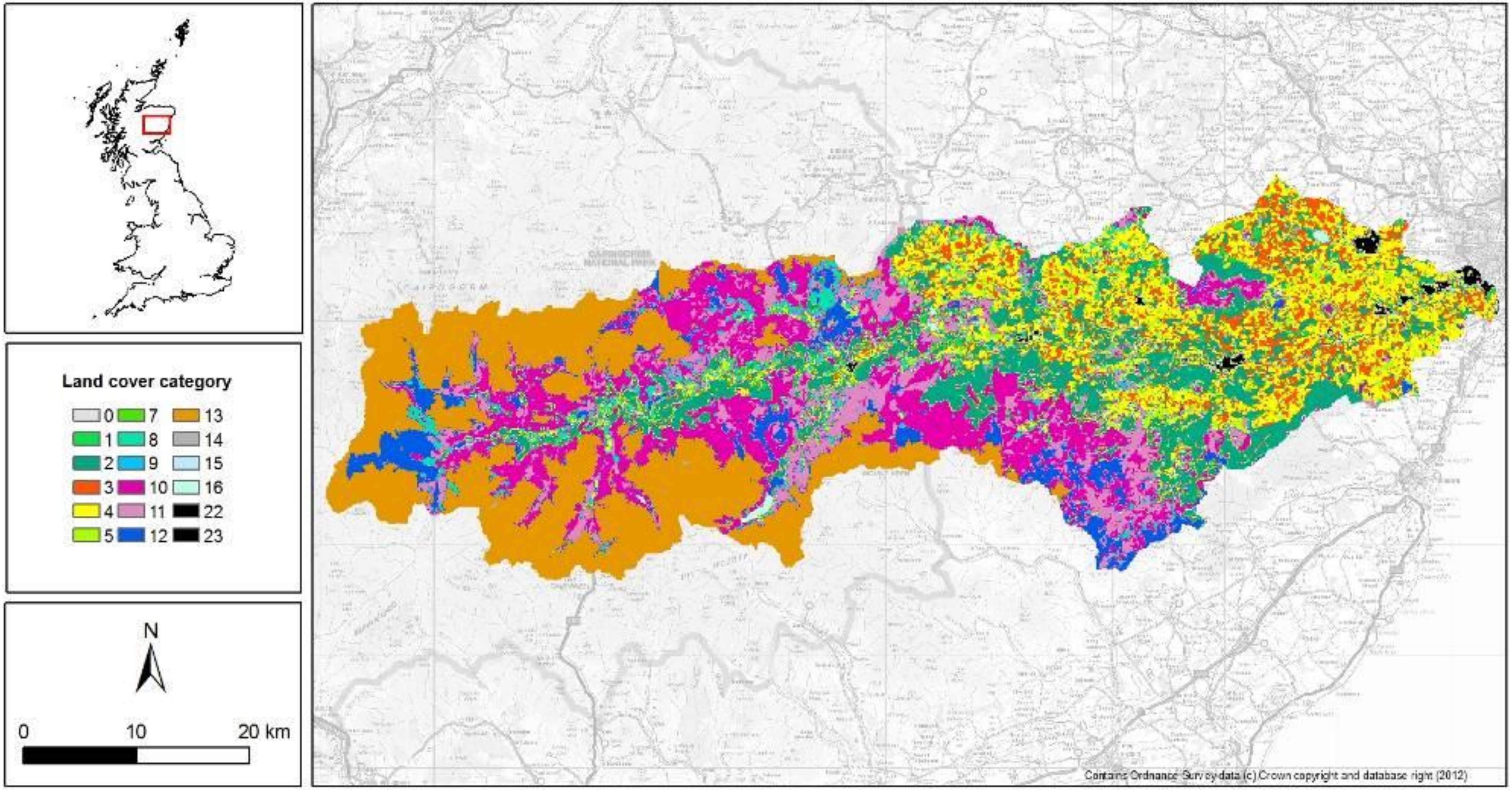
The HEC-HMS catchment scale hydrological routing model used for the floodplain measures was also used to model the effects of potential out-of-floodplain measures, with input flows generated using ReFH. In order to simulate re-naturalisation of the hydrology in the generation areas of the River Dee catchment, the catchment description parameters within the ReFH model were altered. This was used to provide an analogue for what might be considered more 'natural' land use and drainage.

The BFIHOST[1] and SPRHOST[2] parameters were identified as the parameters influenced by land cover within the FEH CD ROM v3 catchment descriptors database. However, it was decided that only BFIHOST would be used in the subsequent analyses since it is based on a more comprehensive data-set (daily runoff) which is more widely available than hourly event data used for SPRHOST estimation. The ReFH also defaults to using BFIHOST over the SPRHOST because it is based on a more comprehensive data-set.

Land cover data was taken from the LCM2007 dataset (Figure 3.4). This was used to select five control sub-catchments, which had consistent land cover characteristics (i.e., one land-use type within their area) that represented either impacted (heather, coniferous woodland and improved grassland) or 'natural' (montane habitat and broadleaved woodland) conditions in the Dee sub-catchments (shown in Table 3.4). These control sub-catchments were of similar size, geographic location and altitude range to each other, which minimised the likelihood of difference between catchment descriptor parameters other than those influenced by land-cover. These control sub-catchments were used to determine the BFIHOST values for the differing land covers as shown in Table 3.4.

[1] Base Flow Index derived for the HOST soil classification

[2] Standard Percentage Runoff (%) associated with each HOST soil class



Notes: See Table 3.3 for explanation of codes	cbec		*River Dee Restoration* **Dee land cover**
		Project No. U13-1008	Created By: CM	**Figure 3.4**

Table 3.3 Land cover categories

Land Use ID	Description	% area of Dee catchment	Altitude range (m)
1	Broadleaved woodland	2.9	0-400
2	Coniferous woodland	14.5	0-500
3	Arable and horticulture	6.5	0-250
4	Improved grassland	11.6	0-250
5	Rough grassland	2.4	0-250
7	Calcareous grassland	0.0	0-400
8	Acid grassland	3.8	0-650
9	Fen, marsh and swamp	0.0	0-550
10	Heather	18.5	200-800
11	Heather grassland	9.4	100-800
12	Bog	4.9	100-600
13	Montane habitats	23.7	500>
14	Inland rock	0.1	N/A
15	Saltwater	0.0	N/A
16	Freshwater	0.6	N/A
22	Urban	0.2	N/A
23	Suburban	0.9	N/A

Table 3.4 Catchment descriptors for the five land cover types represented by the control sub-catchments[3]

Descriptor	Impacted land cover			Natural land cover	
	Heather	Coniferous Woodland	Improved Grassland	Montane Habitat	Broadleaved Woodland
AREA (km^2)	4.15	4.05	2.92	4.14	2.93
ALTBAR (m)	577	308	222	734	133
PROPOWET	0.63	0.53	0.54	0.68	0.53
BFIHOST	**0.508**	**0.617**	**0.549**	**0.559**	**0.603**
DPLBAR	2.18	2.97	1.64	1.86	1.81
DPSBAR	256.3	97.5	147.5	112.1	88.2
SAAR	1009	826	828	1461	814
URBEXT1990	0	0	0	0	0

The altitude ranges of the different land cover types in Table 3.4 were compared and the land cover types divided into three altitude categories, as shown in Table 3.5. Figure 3.5 indicates the distribution of the three altitude categories across the Dee catchment. The BFIHOST values of the impacted and re-naturalised land cover types in each of these altitude categories were then compared and a percentage increase was derived as shown in Table 3.5

No control catchment was suitable to represent rough grassland land use. It was assumed that changing 'improved grassland' to 'rough grassland' would have a similar effect as 'heather' to 'montane habitats'. Therefore, the BFIHOST percentage increase for 'heather' to 'montane habitats' (10.04%) was applied to 'improved grassland' to generate a BFIHOST value of 0.604 for rough grassland. Arable and horticulture land uses were not considered because these types are not typically found in the headwater flow generation areas of the catchment in which the out-of-floodplain measures would be applied.

[3] **Descriptor definitions** – AREA: Catchment area; ALTBAR: Mean catchment altitude; PROPWET: Proportion of time when soils were defined as wet (moisture deficit equal to, or below, 6mm) during 1961-90; BFIHOST: Base Flow Index derived for the HOST soil classification; DPLBAR: Mean of distances between each node on IHDTM grid and the catchment outlet (km) - characterises catchment size and configuration; DPSBAR: Mean of all the inter-nodal slops for the catchment (in km-1) - characterises the overall steepness; SAAR: Average annual rainfall in the standard period (1961-90) (mm); URBEXT1990: Extent of urban and suburban land cover in 1990 (fraction).

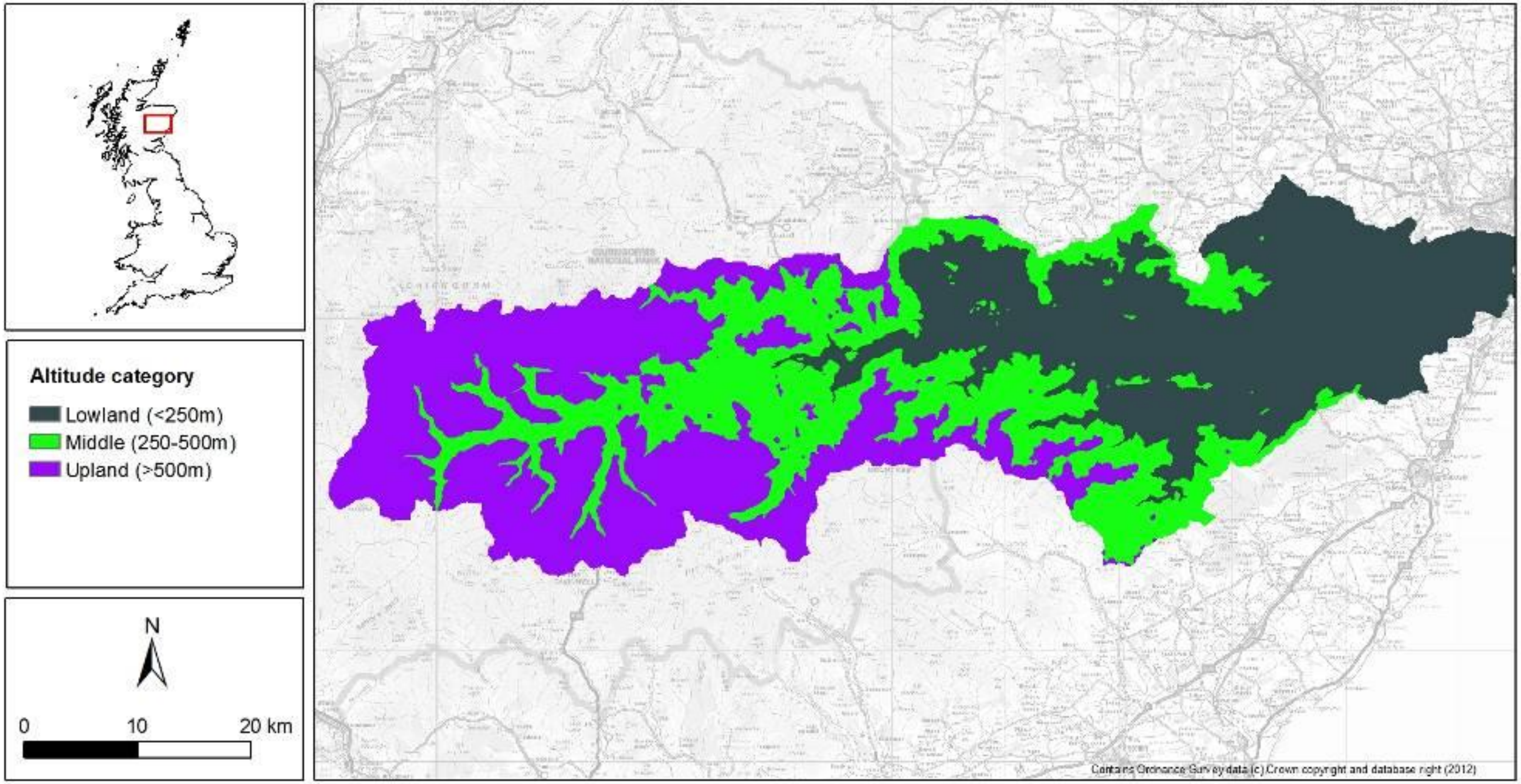
Table 3.5 Percentage changes in BFIHOST associated with land cover re-naturalisation

Status	Land cover	BFIHOST	% Increase in BFIHOST	Altitude Range (m)	Category
Current	Improved grassland	0.549	N/A	0-250	Lowland (<250m)
Re-naturalised	Rough grassland	0.604	10.04%	0-250	
Current	Coniferous woodland	0.617	N/A	0-500	Middle (200-500m)
Re-naturalised	Broadleaved woodland	0.603	-2.32%	0-400	
Current	Heather	0.508	N/A	500>	Upland (>500m)
Re-naturalised	Montane habitats	0.559	10.04%	200-800	

The proportional changes in BFIHOST associated with changes from impacted to natural land cover assume that the land cover across the entire sub-catchment is altered. In reality, land cover varies and some areas already contain 'natural' land cover types. Therefore, the increase in BFIHOST used to represent land cover re-naturalisation was a proportion of the increase shown in Table 3.5, relative to the area covered by the impacted land cover type. For example, if 50% of the land cover in an upland catchment was 'heather' the BFIHOST would be increased by 5.2% (rather than 10.4%) to simulate half of the catchment being re-naturalised to 'montane habitat'.

The ReFH model was used to create flood hydrographs using the FEH catchment descriptors. This allowed the BFIHOST parameter to be altered to simulate an idealised re-naturalisation of land-cover/ drainage throughout the catchment. This was the only parameter changed throughout the process, to ensure that only the effects of land cover change were modelled. The model was used to simulate the effects of land use/drainage re-naturalisation in each of the headwater water bodies with impacted land uses, where re-naturalisation in one water body represented one model scenario. The resulting peak flow was assessed at the outlet of the water body and at four compliance points on the main stem Dee, in order to assess the effects at both the local and catchment scale. The flows from each scenario were compared with the baseline scenario (i.e. current conditions), as generated in Section 3.2.2, to determine the predicted degree of change.

The results allow prioritisation of water-bodies through estimated proportional decrease in peak flows resulting from re-naturalisation of land-use and drainage patterns at the water-body scale. It is likely that changes to 'time to peak' would also be witnessed from land use/ drainage re-naturalisation and, indeed, it may be this effect that has the greatest potential for flood risk reduction for 'out-of-floodplain' measures. However it was not possible to simulate this using the ReFH method. The results presented below therefore consider only changes to peak flows. It is advised that more detailed hydrological analysis (modelling) should be implemented to identify the potential benefit to downstream flood risk from the de-synchronisation of flood peaks from contributing water bodies through land-use/ drainage management in flow generation areas.



Notes:	cbec	*River Dee Restoration* **Dee altitude categories**	
		Project No. U13-1008	Created By: CM	**Figure 3.5**

3.3.2 Out-of-floodplain measures modelling results

The full results of the modelled influence of land cover and drainage re-naturalisation are given in Appendix E. A summary of the results is presented in Table 3.6 and shown on Figure 3.6. The proportional reduction in flow at the water body outlet was taken to represent the impact on flood flows at the local scale, while the proportional reduction in flow on the Dee at Culter (near to the tidal limit of the Dee) was taken to indicate the influence on flows at a catchment scale.

Table 3.6 indicates that land use/ drainage re-naturalisation in Brodiach/Ord Burn is predicted to result in the greatest local impact to flows, with a reduction of 16.7% to peak discharge magnitude. This, together with the other top seven water bodies in Table 3.6, is in the lowland altitude zone where improved grassland is the dominant land use. This indicates that re-naturalisation of large areas of improved grassland, particularly in these water bodies, is likely to have the greatest effect on reduction of flood peaks.

The greatest predicted percentage reduction of flow at Culter resulting from land use re-naturalisation in any single water body was 0.59 %, indicating that even when undertaken at the scale of a water body, land use changes are unlikely to result in a significant reduction in flood peaks at the catchment scale. Re-naturalising land cover in all headwater water bodies resulted in a 1.74% flow reduction at Culter, which is also unlikely to be of significant benefit to flood risk. However, note that this does not consider the potential reduction in flood flow through the mechanism of de-synchronising flood peaks from contributing water bodies.

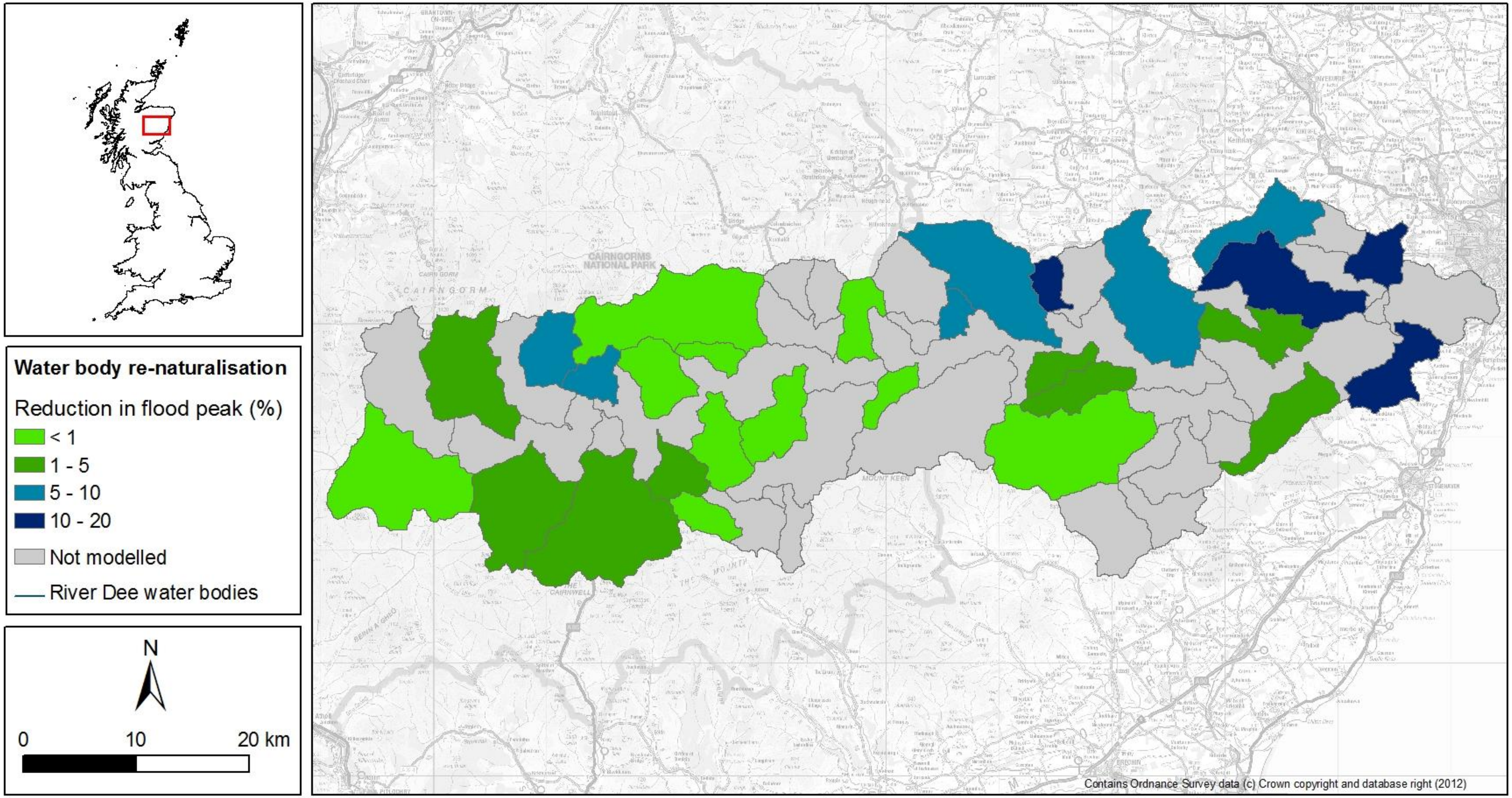
Similarly to the modelling of floodplain reconnection measures, it should be recognised that the modelled values of flow attenuation are intended simply as a means of high level comparison between water bodies and the absolute output values of flow are subject to a considerable degree of uncertainty. However, the relative values can be used to determine the water bodies where the greatest potential for out-of-floodplain NFM measures exists.

Despite the uncertainty over absolute values, the fact that measures that have a significant local impact on flood peaks have very little effect at the main stem Dee downstream compliance point (i.e. at Culter) can be used to draw the conclusion that out-of-floodplain NFM measures are unlikely to contribute to significant flood risk reduction at the catchment scale. However, note that this does not consider the potential reduction in flood flow through the mechanism of de-synchronising flood peaks from contributing water bodies.

Given the differences in spatial scale and modelling approach between out-of-floodplain and floodplain NFM measures, it was not considered appropriate to directly compare the predicted changes resulting from the two types of measure. The options for NFM through out-of-floodplain measures have therefore been assessed and ranked separately from the floodplain reconnection measures. Given the very small predicted effects at the catchment scale, the percentage reduction in flow at water body outlet (i.e. local scale change) was used as the score for NFM potential, as shown in Table 3.6. Also note that, given their broad spatial scale of application, out-of-floodplain NFM measures could not be directly integrated with the subsequent prioritisation of restoration options (Section 5).

Table 3.6 Predicted decreases in flow resulting from water body re-naturalisation

Re-naturalised water body	Water body ID	Reduction in flow at water body outlet (%)	Reduction in flow at Culter (%)
All		N/A	1.74
Brodiach Burn / Ord Burn	23322	16.7	0.48
Crynoch Burn	23317	14.5	0.41
Gormack Burn	23320	11.4	0.58
Dess Burn - upper stretch	23337	11.2	0.51
Tarland Burn	23338	7.1	0.52
Davan Burn	23340	6.7	0.49
Beltie	23333	5.7	0.53
Slugain Burn	23360	5.5	0.45
Kinnernie Burn	23323	5.4	0.49
Quoich Water - Allt Dearg	23364	5.1	0.40
Sheeoch Burn	23318	4.0	0.45
Clunie Water - upper catchment	23362	3.1	0.30
Lui Water	23366	3.1	0.59
Ey Burn	23365	3.0	0.46
Burn of Birse	23335	2.8	0.43
Burn of Cattie	23334	2.1	0.43
Bo Burn	23324	1.9	0.43
Allt Lochan Nan Eun	23359	1.6	0.42
Geldie Burn	23368	0.9	0.44
Tullich Burn	23343	0.6	0.0
Girnock Burn	23355	0.4	0.0
River Gairn - upper catchment	23350	0.3	0.04
Water of Aven / Feugh - upper catchment	23331	0.2	-0.01
Crathie Burn	23356	0.2	0.01
Gelder Burn	23358	0.0	0.01
Pollagach Burn	23344	0.0	0.00
Feardar Burn	23357	0.0	-0.01
River Muick - Allt an Dubh Loch	23354	-0.1	-0.03
Water of Tanar	23339	-0.4	-0.04
Water of Dye - upper catchment	23329	-0.4	-0.07



Notes:	cbec	*River Dee Restoration* **Predicted reduction in flow from water body re-naturalisation**		
		Project No. U13-1008	Created By: CM	**Figure 3.6**

4. STAKEHOLDER ENGAGEMENT

4.1 INTRODUCTION

The River Dee is unusual in that it has a long history of stakeholder engagement, with a wide range of stakeholder projects, events and meetings held since the mid 1990s. The Dee Catchment Partnership (DCP), which includes the key stakeholders within the catchment, has also been in existence for the last ten years. It was important that the pilot catchment project took due cognisance of this history and sought to use and develop existing partnerships, rather than to build new stakeholder engagement mechanisms.

The River Dee is a reasonably large river catchment within Scotland and encompasses a broad range of stakeholders, from a local authority covering a large urban area, through to landowners and private estates with many thousands of hectares of open moorland. No single mechanism could engage all these stakeholders and therefore a variety of approaches are required throughout the project duration.

In order to keep track of all engagement activities a log has been developed which will continue to be developed over future project phases.

4.2 METHODS

4.2.1 Liaison with the existing catchment partnership

Recognising the extensive past history of stakeholder engagement and the presence of an existing catchment partnership (DCP) was an important first step for this project. In light of this, immediately following project start-up, an introductory meeting was organised with the catchment partnership project officer and the chair of the partnership steering group. This took place at the SEPA offices in Aberdeen on March 22nd, 2013. The meeting provided an opportunity to recap on the aims and objectives of the project and to discuss potential joint working. The main outcome from the meeting was an agreement to undertake a consultation workshop with stakeholders within the catchment partnership to gather data on specific sites within the catchment. The DCP felt that this would help to ensure that past discussions with landowners were not duplicated by the pilot catchment project and would also ensure that the contractors were aware of previous activities undertaken at potential restoration sites.

It was also agreed that a summary of the project would be passed onto DCP members by the project officer. A summary was prepared and submitted to the DCP for further distribution.

4.2.2 Stakeholder workshop

To gather information on existing work within the catchment and to provide further information on the proposed approach for this project, a full day workshop was held for key stakeholders, including members of the DCP. All members of the DCP were invited to this meeting along with some additional stakeholders. The meeting was held at the SEPA offices in Aberdeen and took place on May 30th, 2013. Prior to the meeting, the following information was distributed:

- A summary of the project
- A map highlighting locations of potential restoration reaches
- An email providing details of the background information that was sought for these areas

The workshop commenced with a short presentation on the project, before splitting the attendees into two working groups. Each group focused on a different section of the river and information was collected concerning previous and planned activities within that area.

The second section of the workshop focused on the process to be used to prioritise sites later in the project. Some discussion of potential factors which could be included within this site prioritisation process took place. Participants were asked what additional factors they would like to see included and suggestions received were:

- Timescale for delivering work
- Regulatory compliance on site
- Cross funding
- Delivery mechanisms /sponsor – can it be delivered in the timescale and by whom?
- Complexity of land ownership at the site

Participants were also offered the opportunity to review the prioritisation process prior to the sites being scored, but the consensus of the group was that they were happy for the contractors to develop an appropriate process. Instead, they wanted to see the initial list of potential sites and to provide their comments on potential delivery mechanisms at each site, which would be considered outwith the main MCA process.

4.2.3 Wider awareness raising with land managers

In recognition of the importance of effective engagement with land managers, SEPA developed catchment-specific postcards for all four catchments involved in the pilot project. The aspiration was to circulate postcards to all land managers within the catchment to ensure everyone was aware before the project started. However, data protection issues prevented access to the required address information.

The following alternative circulation options were then agreed, which were undertaken between May-July:

- An electronic version of the postcard and a summary of the project were provided to both Scottish Land and Estates and the National Farmers Union for Scotland to send to their members within the Dee catchment area. This information was distributed by these organisations by email in mid May 2013.
- Areas where field surveyors would be working (Beltie Burn, Lower Feugh and the main stem of the Dee between Banchory and Peterculter) were targeted as a priority for engaging with land managers, and a mailing list prepared from information provided by SEPA. It was recognised that this would not cover all land managers within these areas and that additional approaches would be necessary to try and ensure maximum coverage.
- Additional copies of the postcard were placed within the SNH / SEPA office in Aberdeen and copies of the postcard were also provided to the Dee Catchment Partnership. Postcards were supplied to SNH and RPID for distribution from their offices.
- The on-site field survey team carried hard copies of the postcard which could be passed to land owners they met when on site. Survey work was undertaken in June and July and only

one landowner was encountered who was unaware of the project. He was provided with a hard copy of the postcard by the surveyors.

4.3 STAKEHOLDER CONSULTATION OF OPTIONS

The ranked listing of potential restoration sites resulting from the MCA was distributed to stakeholders, along with a document which summarised the approach that had been taken for ranking the sites and a map showing site locations. Stakeholders were asked to provide feedback on the sites, including:

- Any knowledge of previous discussions with landowners
- Stakeholder support for the action
- Potential delivery mechanisms for implementing the action

Feedback from stakeholders was variable, with some stakeholders concerned that the timescale for responses was too short (2 weeks). Other stakeholders wanted more detail on the prioritisation process and the type of works that could be undertaken at each site. Due to internal deadlines within SEPA, it was only possible to extend the timescale for responses by another few days. Additional information on the prioritisation process was not provided at this stage, as there was no scope for changing the approach and it would have been disingenuous to ask stakeholders to spend time reviewing the detail of the process, when their feedback could not be incorporated. Instead, they were asked to focus on the listed sites and provide their local knowledge on likely issues and challenges at the sites.

Other stakeholders were happy to comment on the documents and provided a range of responses. These can be summarised as:

- The importance of taking a catchment approach to site selection. Greatest ecological benefit may not be achieved by working through the sites in a strict hierarchy, starting at number 1 and continuing down the list. Greater ecological benefit may be obtained by focusing on several sites within one tributary and delivering the most highly ranked sites within that tributary, rather than sites which are scattered more widely across the whole catchment.
- The need to consult with stakeholders on detailed plans at sites, particularly those stakeholders involved in maintaining critical infrastructure.
- The potential for additional benefits from sites, such as the creation of riparian woodland.

A final presentation of the project's findings is proposed for the Dee catchment. This will provide a further opportunity to raise awareness of the project prior to moving to the implementation stage.

5. MULTI-CRITERIA ANALYSIS OF OPTIONS

Following identification of potential morphological restoration options (Section 2.5) and potential natural flood management (NFM) opportunities (Section 3) in the Dee catchment, the two sets of opportunities were integrated in order to undertake multi-criteria analysis (MCA). Also incorporated in the MCA was further ecological and socio-economic information that allowed assessment of the secondary benefits, and any constraints, associated with the restoration options.

MCA was used as a semi-quantitative means of assessing the multiple benefits associated with undertaking restoration actions at each identified location and, through this, to prioritise opportunities that provided the greatest overall benefit. This section describes the MCA and explains the rules used to score/ weight options for each of the criteria. The results of the MCA are provided in Appendix G.

5.1 INTEGRATION OF WFD AND NFM OPTIONS AND INITIAL SCREENING

The locations of potential WFD restoration and NFM opportunities (Appendix C and Appendix E) as generated through the initial prioritisation exercise (Sections 2.5 and 3.2.4), were spatially integrated to produce a combined list of 63 locations where either one or both issues could be addressed. Given the importance of embankment removal, both for NFM and for freeing up morphological 'capacity used' (as per MImAS terminology), the NFM opportunities generally coincided with WFD restoration opportunities. Any potential NFM measures in locations that did not have an opportunity for WFD restoration were removed from the combined list and have been assessed separately in Section 3. The reaches defined in the analysis of WFD restoration opportunities were used to define the extent of each restoration opportunity taken forward to the MCA.

An initial screening of the list was undertaken, based on the following rules and assumptions, to reduce the options to a manageable number for MCA.

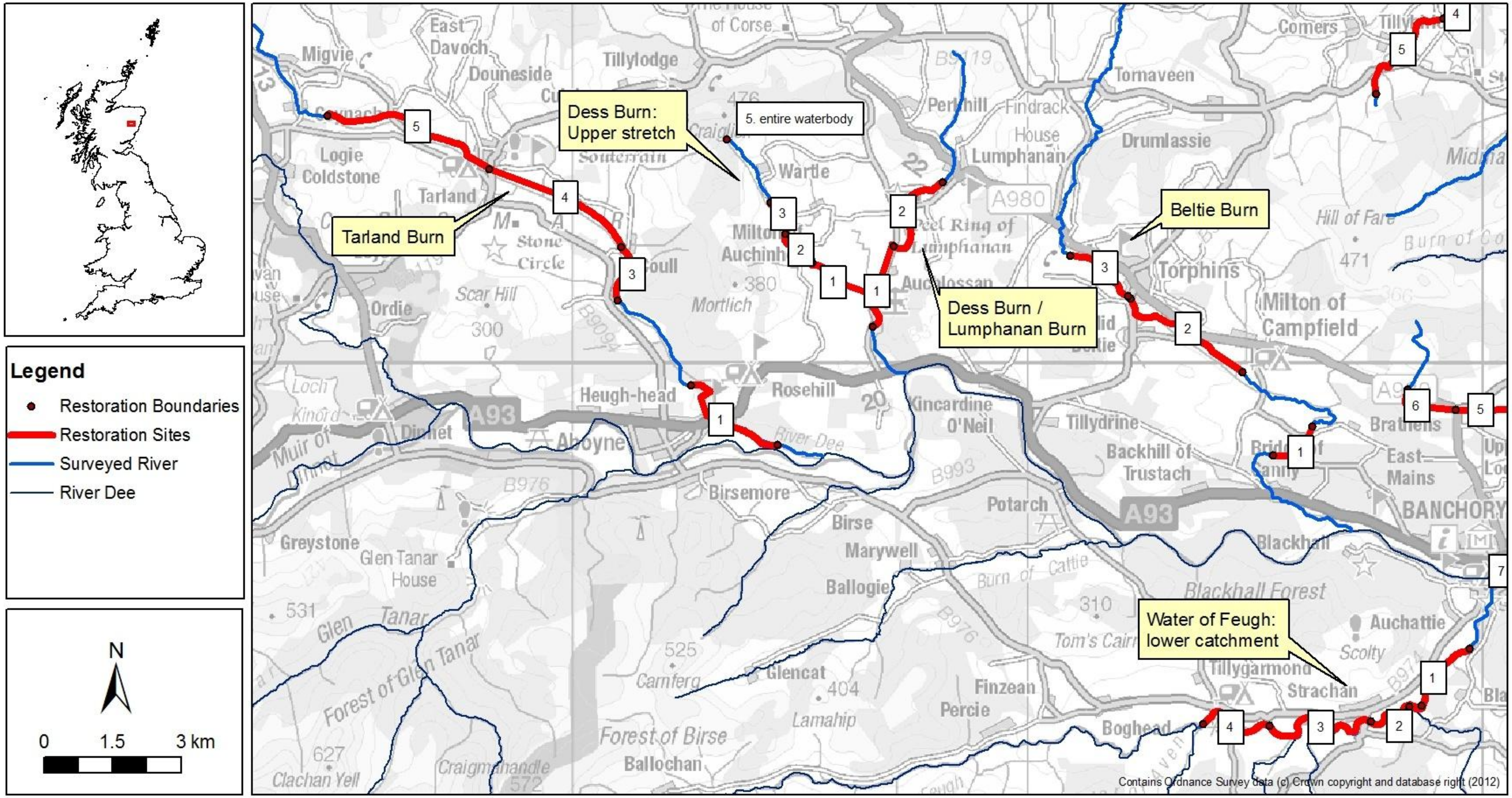
- Most restoration reaches included several restoration actions to address multiple pressures. The first assumption was that, within a restoration reach, all identified restoration actions would be addressed, where possible, because this would constitute a more cost-effective approach to achieving benefits. Therefore, each restoration reach in the list represented one restoration option within the MCA (i.e. different combinations of possible restoration actions within a reach were not considered).
- It was also assumed that it would be preferable for embankments and high impact realignment (HIR) to be addressed by full removal/ mitigation, rather than by changing to set back embankments/ low impact realignment (LIR), so these were the actions that were addressed in the MCA at this stage. Subsequently, more detailed analysis of the favoured options may indicate that full removal of embankments or HIR is not feasible due to cost or other site-specific issues, in which case the alternative options of changing to set back embankments/ LIR could be considered instead.
- A set of rules was used to remove options that were considered to have a minor benefit on morphological capacity used. These are summarised in Table 5.1. Thresholds were set for capacity released. Measures that released less capacity than this threshold were excluded from the list of options. An exception to this was where a measure to address embankments or in-channel pressures released less capacity than the threshold, but coincided with a

measure to mitigate realignment, as it was assumed mitigation of realignment would also address embankments and in-channel pressures (e.g. bank protection and croys) as part of the restoration works. A further exception was where inclusion of the measure allowed sufficient release of capacity to increase water body status class. Measures to remove embankments that released less capacity than the threshold were also retained if they coincided with a reach identified as having significant NFM potential.

Following the screening process, a total of 45 restoration options were taken forward to MCA. The locations of these are indicated on Figure 5.1 and Figure 5.2. Grid references of reaches are given in Appendix G.

Table 5.1 Summary of criteria for including restoration measures in list of options

Pressure being addressed	Criteria for inclusion in list of options
Embankments	> 5% capacity released in reach, or located in the same reach as HIR or LIR mitigation, or contribute to increase in water body status as part of option, or be in same reach as significant NFM measure.
HIR, LIR	> 5% capacity released in reach (between both types of realignment) or contribute to increase in water body status as part of option.
Bank protection, croys, weirs, culverts	> 2% capacity released in reach (between all pressures), or be in the same reach as HIR or LIR, or contribute to increase in water body status as part of option.
Riparian vegetation loss	Be in the same reach as another option.



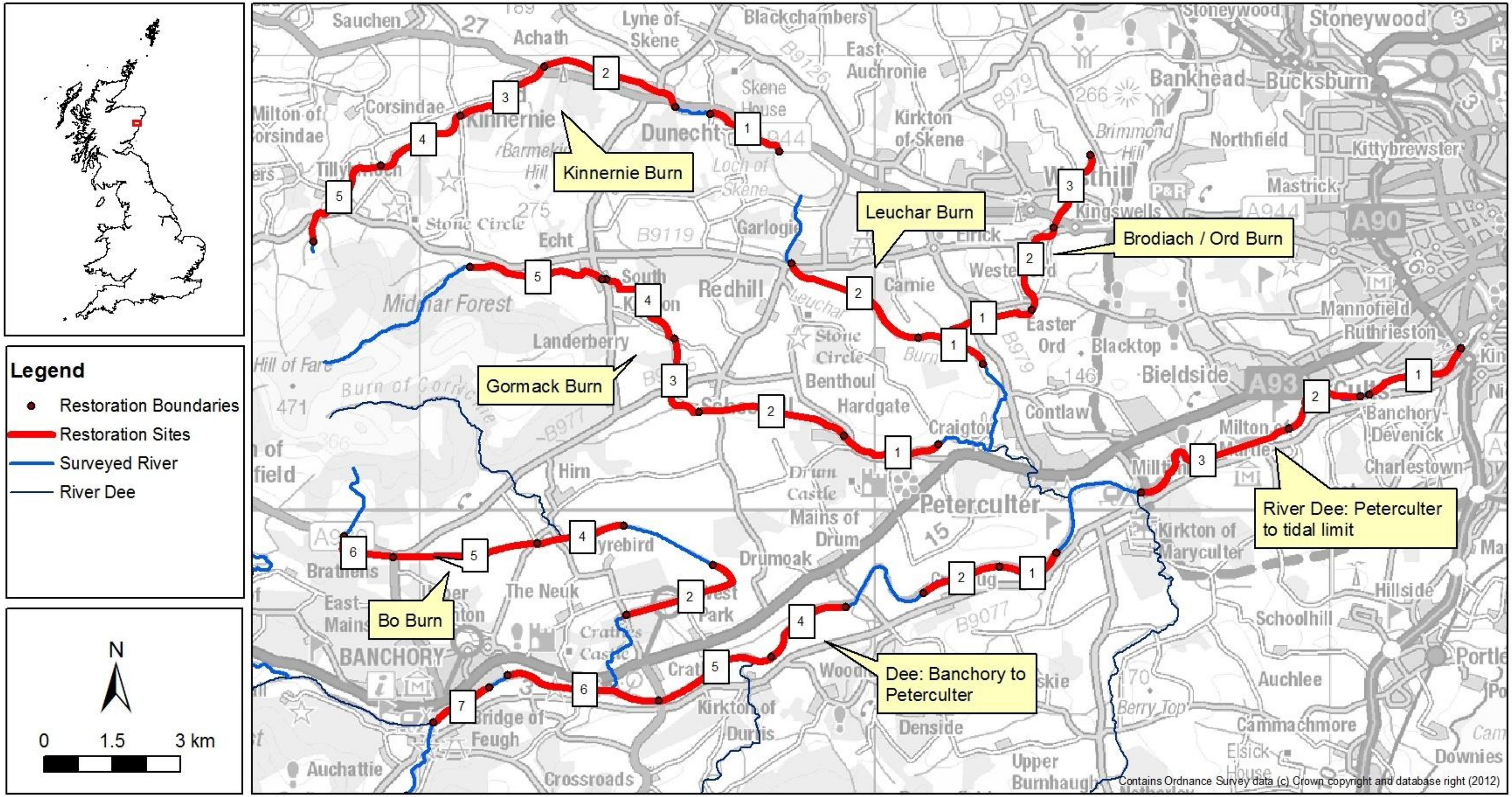
Notes:
The restoration reach numbers within each water body correspond to the reach numbers in the MCA table (Appendix G).

cbec eco engineering

River Dee Restoration

River Dee restoration reaches – west

Project No. U13-1008	Created By: GK	**Figure 5.1**



Notes:
The restoration reach numbers within each water body correspond to the reach numbers in MCA table (Appendix G).

River Dee Restoration

River Dee restoration reaches – east

Project No. U13-1008	Created By: GK	**Figure 5.2**

5.2 SCORING OF MCA CRITERIA

5.2.1 WFD status for morphology

The score for the benefit of the option to WFD status for morphology was based on whether the option contributed to an increase in water body WFD status for morphology and on the MImAS percentage capacity released. The scores assigned are shown in Table 5.2. An option that improved status by two classes to good would receive all three scores in rows one to three (i.e. a total of 2.25), as well as a score relative to its overall capacity released.

Table 5.2 Scoring criteria for morphological benefit

Criterion	Score
Improves status to good	1
Improves status by 2 classes	0.75
Improves status by 1 class	0.5
Capacity released	Percentage capacity released reclassified from 0 to 0.25

5.2.2 Natural flood management

The scores for each option relating to NFM benefit were the adjusted and weighted scores determined in Section 3.2.4 and provided in Appendix E. Out-of-floodplain measures were not included in the MCA because none of them directly coincided with a morphological restoration option. However, these could be taken forward separately as part of an NFM plan for the catchment.

5.2.3 Environmental criteria

Options were scored for various criteria relating to their additional benefits to habitat and ecological receptors. This assessment was carried out using on desk-based information, expert judgment and existing local knowledge of the project team. Given that there was no scope for undertaking site visits as part of this assessment, information about site-specific factors was limited. For each criterion a set of simple rules was used to determine the assigned score. These are described below. The simple scores reflect the high level, desk-based nature of this assessment.

5.2.3.1 Impact on nationally designated protected areas

Much of the Dee catchment is designated as a Special Area of Conservation (SAC). Initially, consideration was given to scoring reaches within the SAC more highly. However, those tributaries that are outwith the SAC still have the potential to impact on the SAC; therefore, this approach was discounted. It was decided instead to assess impacts on the designated features of the SAC (described below), rather than on the area of the SAC.

There are some additional protected areas within the catchment (SSSIs) and the potential to impact on these is recorded within this category. The relevant reaches which are affected are:

Bo Burn reach 2 - bisects Loch of Park SSSI which is designated for its basin fen (wetland) features. Potential actions on this reach include removing embankments and realignment which could have a positive effect on the wetland features.

Gormack Burn reach 1 – is adjacent to the Old Wood of Drum which is designated for its woodland features. Potential actions on this reach include removing embankments and realignment which could have a positive effect (or negative, depending on the precise species mix at the woodland / burn interface) on the woodland features.

5.2.3.2 Impact on internationally designated species

The Dee is designated as an SAC for freshwater pearl mussel, otter and salmon. Locations for these species within the catchment are known, so one option that was considered was to score reaches more highly if they have these species present within them. However, this would not pick up on the value of works which could potentially increase available habitat areas for these species in sections where they are not currently normally present, ultimately leading to the potential for an increased range.

To reflect this, scores were allocated based on the likelihood of the potential restoration options improving the habitat required by the species, as shown in Table 5.3 to Table 5.5. It should be noted that the scores are general assumptions. In all cases, a site specific assessment would need to be made to confirm conditions. For example, in some cases, a realigned/ bank protected section of river may have stabilised in such a way that the bed sediment is highly suitable for freshwater pearl mussel. In this case, realignment back to a more natural form could have a negative impact on pearl mussel, even though one would generally expect realignment to introduce greater habitat diversity to a river, which would normally benefit instream ecology generally.

Table 5.3 Scoring criteria for impact on salmonids

Score	Impact	Measures included:
1	Positive	Re-alignment, restore bankside vegetation, remove bank protection
0	Neutral	Removal / set bank embankments, removal of croys, removal of weirs

Table 5.4 Scoring criteria for impact on otters

Score	Impact	Measures included:
1	Positive	Re-alignment, restore bankside vegetation, remove bank protection
0	Neutral	Removal / set bank embankments, removal of croys, removal of weirs

Table 5.5 Scoring criteria for impact on freshwater pearl mussel

Score	Impact	Measures included:
1	Positive	Re-alignment, removal of weirs
0	Neutral	Removal / set bank embankments, removal of croys, restore bankside vegetation, remove bank protection

5.2.3.3 Surrounding habitat creation potential

Sites were scored according to whether they could provide an opportunity to link existing areas of habitat which were adjacent to the reach. Ideally, this should be done using a habitat network approach, by modelling the dispersal distances of suitable focal species (in this case, a wetland species would be most useful) and highlighting where habitat creation/ restoration has the potential to increase functionally connected areas of habitat. However, no habitat network models have been produced for the catchment, so an assessment of potential habitat connectivity (and how it could be enhanced by the proposed restoration actions) had to be made from satellite imagery. Wetland habitats can be difficult to detect accurately on satellite images, so only woodland and heathland habitats were used. Generally it is possible to detect the extents of these habitats on satellite images, although it is not possible to assess the quality of the habitat block.

The following scores were used:

1 – limited woodland or heathland habitat adjacent to the restoration reach, therefore limited potential to increase habitat connectivity

2 – some small areas of woodland or heathland habitat adjacent to the restoration reach, but the small size of the individual patches means that they have limited quality. There is potential to connect these habitats during the restoration work, but the overall habitat area created and / or connected will still be relatively small.

2 – significant areas of woodland or heathland habitat adjacent to the restoration reach, but the measures proposed are unlikely to create additional habitat and therefore the patches will be likely to remain separated and overall connectivity will not increase.

3 – significant areas of woodland or heathland habitat adjacent to the restoration reach, and the restoration work proposed is likely to increase habitat areas and therefore result in additional connectivity of habitats.

5.2.3.4 Potential to mitigate diffuse pollution

Some restoration measures can also contribute to tackling diffuse pollution issues. To assess the potential for this within these sites, each reach was assessed to establish whether it was failing WFD water quality standards, using parameters which are most commonly associated with diffuse pollution (diatoms and phosphorous levels). For those which are failing, there is potential for the proposed measures to help to reduce diffuse pollution. Scores were therefore applied as shown in Table 5.6.

Table 5.6 Scoring criteria for potential to reduce diffuse pollution

Score	Potential to reduce diffuse pollution?	Definition
2	Yes, possible	Reach is failing WFD water quality standards (diatoms and/or phosphorous).
0	No	Reach is not failing WFD water quality standards (diatoms and/or phosphorous).

5.2.4 Socio-economic criteria

Options were scored using a similar approach to the environmental criteria, based on a set of simple rules and generally from desk-based information sources. Information from stakeholders was used to provide site-specific information where relevant. For example, this included information on plans to develop additional recreational resources, or other adjacent opportunities for awareness-raising.

5.2.4.1 Impact on critical infrastructure

Critical infrastructure within the Dee catchment was considered to include all roads, railways, Scottish Water assets and the main gas and oil pipelines which cross the river.

Ideally, impacts on critical infrastructure should be assessed on a site by site basis. For example, a re-alignment project may still be possible, even with critical infrastructure within the reach, provided it is carefully designed. However, in order to take account of the additional constraints that this presents, sites were scored as shown in Table 5.7.

Table 5.7 Scoring criteria for impact on critical infrastructure

Score	Impact	Definition
0	None	No critical infrastructure within the reach, or if critical infrastructure is present, but the measures proposed are unlikely to impact on it (e.g. removal of croys is unlikely to impact on a Scottish Water asset, but realignment could)
-1	Possible	Critical infrastructure exists within the reach and could potentially be impacted by the work.

5.2.4.2 Potential to create recreational infrastructure

Some sites may offer the potential to incorporate recreational infrastructure (paths, community wetland areas etc.) within their development. Again, this should be assessed in more detail on a site-by-site basis in discussion with stakeholders. However, in order to highlight potential developments, scores were assigned as per Table 5.8

Table 5.8 Scoring criteria for potential to create recreational infrastructure

Score	Potential	Definition
2	Yes, possible	Stakeholder comments have shown that there is already interest in developing / using recreational assets within the reach, or if the reach is close to an existing recreation asset, or if it is within an area marked for development within the local plan (where recreational opportunities could potentially be incorporated in new developments)
0	No, unlikely	No stakeholder comments, no existing recreational assets, not within a development area.

5.2.4.3 Awareness raising potential

Large restoration projects could potentially be used to raise awareness of river restoration actions and processes. However, not all sites are suitable; some sites may be too inaccessible, or too far from existing settlements. It is important that opportunities to tell local communities about the work are taken up.

To account for the potential to use a site for awareness raising, the following scores were used (Table 5.9).

Table 5.9 Scoring criteria for awareness raising potential

Score	Potential	Definition
2	Yes, possible	The site is within 7 km of a settlement of greater than 2000 people (so there may be potential for local residents to walk to the site), or it is adjacent to an existing path, or stakeholder feedback has highlighted the presence of other environmental awareness raising activities in the area. Sites involving high-impact realignment, close to a road.
0	No, unlikely	Distant from settlements, not adjacent to paths, no stakeholder comments, proposed measures not visible (e.g. removal of croys)

5.3 WEIGHTING AND CALCULATION OF FINAL SCORE

Scores for each of the criteria within the environmental and socio-economic categories were added to give overall scores for these categories. Together with morphology and NFM, this produced four scores for each reach. The reach scores within each category were normalised by transforming to be in the range 0 to 1. Weightings totalling 100 were applied to the four categories to reflect their relative importance within the options appraisal. Morphology and NFM were given a weighting of 35 each, to reflect the fact that they are of equal importance. The environmental score was given a weighting of 20, while the socio-economic score was given a weighting of 10. The higher weighting of environmental, relative to socio-economic, reflects the importance of the Dee as an SAC. It is acknowledged that the weightings are subjective and the numbers used can easily be altered within the spreadsheet if necessary, as required by the SEPA technical working group who are overseeing the project. The normalised reach scores were multiplied by the weighting to get the final score. These four scores were then added to give the overall score for each reach.

5.4 MCA RESULTS

The full MCA table showing the scores applied is provided in Appendix G. A summary of the final scores is provided below (Table 5.10).

The measure which scored highest overall was restoration of the Dee between Milltimber and Ardoe House Hotel. The restoration would include removal of embankments, mitigation of realignment, removal of bank protection and restoration of riparian vegetation. This option scored highest for NFM benefit and also results in the greatest improvement to MImAS capacity released, making it the most favourable option overall by a large degree. It should be noted that the measures in this reach may affect critical infrastructure, including the B9077, which runs adjacent to part of the reach, and potentially the new Aberdeen Western Peripheral Route, which is planned to cross the river in this reach. This could limit the potential to implement all identified measures, with a corresponding reduction in benefit. More detailed assessment is needed to determine this.

The second highest ranked option, restoration of the Leuchar Burn from Garlogie to Broadwater, scored highly because of its potential to increase water body status to good, as well as for having a high degree of additional environmental benefit. Its potential for NFM, however, is very low. The third highest ranked option, restoration of Dess/Lumphahan Burn from Auchlossan to Muir of Dess, also scored highly for WFD, but less high for NFM. Conversely, the fourth highest ranked option, restoration of the Tarland Burn from Tarland to Bridgend Steading, had the second highest score for NFM potential, while having a lower score for morphological benefit.

It is recognised that option feasibility will be affected by a number of factors that were not included in the MCA. A final assessment and prioritisation of options, taking into account cost, constraints and other benefits/ opportunities was carried out following the MCA, in order to produce a ranked list of options based on benefits and practicalities of implementation. This is reported in Section 6.

Table 5.10 Summary of MCA scores

Water body	Reach no.	Reach location	Restoration measures	Overall MCA score
Dee - Peterculter to tidal limit	3	Milltimber to Ardoe House Hotel	Remove embankments; mitigate HIR; mitigate LIR; remove BP; restore vegetation	73.1
Leuchar Burn	2	Garlogie to Broadwater	Remove embankments; mitigate HIR; remove BP; restore vegetation	60.1
Dess Burn / Lumphanan Burn	1	Auchlossan to Muir of Dess	Remove embankments; mitigate HIR; remove BP; restore vegetation	51.7
Tarland Burn	4	Tarland to Bridgend Steading	Remove embankments; mitigate HIR; restore vegetation	41.0
Dee - Banchory to Peterculter	4	Park House	Remove embankments; remove BP; remove croys; restore vegetation	40.3
Brodiach Burn / Ord Burn	1	Downstream Easter Ord Farm	Remove embankments; mitigate HIR; mitigate LIR; restore vegetation	38.8
Tarland Burn	1	Downstream Aboyne Castle	Remove embankments; mitigate HIR; mitigate LIR; remove BP; remove culverts; remove weirs; restore vegetation	35.5
Gormack Burn	2	Milton of Cullerlie to Blackhall	Remove embankments; mitigate HIR; restore vegetation	34.2
Dess Burn - upper	1	Downstream Mill Farm	Remove embankments; mitigate HIR; restore vegetation	32.0
Tarland Burn	5	Hopeswell to Tarland	Remove embankments; mitigate LIR; remove BP; remove culverts; restore vegetation	30.4
Bo Burn	2	Loch of Park to Coy bridge	Remove embankments; mitigate HIR; remove BP; restore vegetation	30.4
Gormack Burn	1	Blackhall to Mid-Anguston	Remove embankments; mitigate HIR; restore vegetation	29.6
Kinnernie Burn	2	A944 Bridge to Dunecht	Mitigate HIR; remove BP; remove culverts; restore vegetation	28.2
Kinnernie Burn	1	Downstream of Craigiedarg bridge	Mitigate HIR; restore vegetation	27.9
Tarland Burn	3	Bridgend Steading to Coull Home Farm	Remove embankments; mitigate HIR; restore vegetation	27.2
Beltie Burn	2	Torphins to Milton of Campfield	Remove embankments; mitigate HIR; remove BP	25.7
Brodiach Burn / Ord Burn	2	B9119 Bridge to Easter Ord Farm	Remove embankments; mitigate HIR; remove BP; remove culverts; restore vegetation	25.6
Beltie Burn	1	West Brathens to Bridgend	Remove embankments; mitigate HIR; remove BP	25.4
Gormack Burn	4	South Kirkton to Milton of Finnercy	Mitigate HIR; mitigate LIR; restore vegetation	24.6
Bo Burn	4	Hirn bridge to Myrebird	Remove embankments; mitigate HIR; mitigate LIR; restore vegetation	24.5
Bo Burn	6	A944 bridge to A944 bridge	Remove embankments; mitigate HIR; mitigate LIR; remove culverts; restore vegetation	24.3

Water body	Reach no.	Reach location	Restoration measures	Overall MCA score
Beltie Burn	3	Wester Beltie to Torphins	Remove embankments; mitigate HIR; restore vegetation	22.2
Bo Burn	5	A944 bridge to Hirn bridge	Remove embankments; mitigate HIR; mitigate LIR; restore vegetation	22.0
Kinnernie Burn	4	Minor bridge to minor bridge	Remove embankments; mitigate HIR; mitigate LIR; restore vegetation	20.7
Kinnernie Burn	5	Upstream minor bridge	Remove embankments; mitigate HIR; mitigate LIR; remove culverts	20.3
Dess Burn - upper	3	Between Loanend and West Mains	Mitigate LIR; remove culverts; restore vegetation	19.5
Leuchar Burn	1	Broadwater to North Linn	Mitigate LIR	19.5
Dee - Banchory to Peterculter	1	North Tilbouries to Altries house	Remove embankments; remove BP; remove croys	18.1
Dee - Banchory to Peterculter	5	A957 bridge to Kirkton of Durris	Remove embankments; remove BP; remove croys; restore vegetation	17.6
Dee - Peterculter to tidal limit	1	Garthdee	Remove embankments; mitigate LIR; restore vegetation	17.0
Brodiach Burn / Ord Burn	3	Upstream B9119 Bridge	Mitigate LIR; remove BP; remove culverts; restore vegetation	16.4
Water of Feugh - lower catchment	1	Burn of Cammie to Inverey House	Remove BP; remove croys; remove weirs	16.2
Kinnernie Burn	3	Minor bridge to A944 bridge	Mitigate LIR; restore vegetation	14.5
Dess Burn - upper	2	Between West Mains and Mill Farm	Mitigate HIR; restore vegetation	14.5
Dee - Peterculter to tidal limit	2	Ardoe House Hotel to Inchgarth Reservoir	Remove embankments	14.2
Gormack Burn	3	Milton of Finnercy to Milton of Cullerlie	Remove embankments; mitigate HIR; remove BP; restore vegetation	14.1
Dee - Banchory to Peterculter	6	Banchory to A957 Bridge	Remove BP; remove croys; restore vegetation	13.3
Dee - Banchory to Peterculter	7	Banchory	Remove BP; remove croys	13.2
Water of Feugh - lower catchment	3	Lady's Bridge to Strachan bridge	Remove embankments	12.2
Gormack Burn	5	Mill of Hole House to South Kirkton	Mitigate HIR; mitigate LIR; restore vegetation	11.6
Dess Burn / Lumphanan Burn	2	Lumphanan to Auchlossan	Mitigate LIR; remove BP; remove culverts; restore vegetation	11.4
Dee - Banchory to Peterculter	2	Craiglug Farm to North Tilbouries	Remove BP; remove croys	8.3
Dess Burn - upper	5	Entire water body	Restore vegetation	6.0
Water of Feugh - lower catchment	2	Strachan bridge to Burn of Cammie	Remove embankments	5.8
Water of Feugh - lower catchment	4	Upstream Lady's Bridge	Remove embankments	5.3

6. FINAL ASSESSMENT OF OPTIONS

The MCA undertaken in Section 5 was based purely on the merits of each option in terms of its benefit to geomorphology, natural flood management, environmental and socio-economic factors. This approach was intended to ensure that options were initially ranked based on their maximum potential benefit. No consideration was made of other factors which, in reality, will have an important bearing on the practicalities of option implementation. These other factors, such as cost and stakeholder co-operation, are discussed below and were used to provide a 'reality check' to the prioritised list of options. The highest priority options once these additional factors had been taken into account were then determined. This check includes an element of expert judgement and, therefore, subjectivity. The assumptions and rules used to assess options are outlined below in order to ensure that the process taken is as repeatable and objective as possible.

While it is acknowledged that certain works in certain areas may potentially have significant impacts on the associated fisheries, the level of assessment undertaken here was insufficient to allow evaluation of the degree of impact and whether positive or negative. As such, this factor was not included in the assessment. Given the significance of the Dee fisheries, it is strongly recommended that the potential impact on fisheries of the options identified is assessed and considered when options are taken forward to detailed consultation/design.

6.1 FACTORS CONSIDERED

The additional factors considered in the final assessment stage and the method of assessment are described below.

6.1.1 Estimated cost

Cost is likely to be an important factor in determining the feasibility of an option. The addition of this factor allowed assessment of those options that provide the greatest benefit, relative to their cost, providing a means of differentiating between options with similar levels of benefit. Given the large number of unknowns about the implementation of each option, there is a large degree of uncertainty about the likely cost. Each option was, therefore, assigned one of five categories of estimated cost (Table 6.1).

The costs were determined based on the length of river to be modified, the nature of the works and the size of the channel. The channel size was divided into three categories, based on catchment area upstream of the site of interest. Within each size category a standard cost per kilometre for each main type of work (e.g. realignment, embankment removal, removal of bank protection), was applied. It was assumed that works would be more expensive in larger channels. The estimated cost includes the stages of further detailed restoration design, ground works and associated site supervision. It does not take into account the value of surrounding land, the possible interference with infrastructure or costs associated with implementing a monitoring programme. The first two of these factors were considered separately in the 'reality check' assessment.

It is possible that unknown, site-specific factors may cause a significant increase in cost. For example, it has been assumed that when removing embankments, all material can be disposed of on-site. If, for some reason, off-site disposal of materials was required, this could cause a significant increase in cost. Furthermore, detailed site investigations that would be required prior to the implementation of a proposed restoration measure may identify other infrastructure (e.g. service pipes/ cables) that could add to construction costs.

Table 6.1 Cost bands assigned to restoration options

Cost band	Cost range (£k)
1	<50
2	50-100
3	100-200
4	200-500
5	>500

6.1.2 Impact on surrounding land and assets

Options that would require the taking of land outside the existing river corridor were identified. These were assumed to be any options that included removal of embankments or mitigation of realignment. The value of land adjacent to each proposed option requiring land-take was determined from the Land Capability for Agriculture dataset (James Hutton Institute) supplied by SEPA. This classifies land based on its potential productivity and cropping flexibility and was taken as an indication of the value of agricultural land (details on LCA classes are provided in Appendix H). In cases where the reach overlapped multiple land capability classes, the highest land value class was taken forward to use in the assessment. While this factor provides a high level assessment of the value of land, it does not take into account other factors besides agricultural productivity that might increase or decrease the value of land (such as angling value or potential development value). These factors cannot be determined at the current level of assessment.

While the impact of options on critical infrastructure was considered within the MCA, it was considered to be an important element of option feasibility and was therefore included as part of the final assessment stage. It is suggested that in order to avoid double-counting, the impact on critical infrastructure is omitted from the MCA stage in future studies of this nature. Options were put into one of three categories in relation to critical infrastructure:

- no impact on critical infrastructure;
- presence of critical infrastructure prevents implementation of option;
- presence of critical infrastructure prevents full implementation of option, but the option could be modified to avoid the infrastructure, with significant benefit retained (e.g. set back embankments, rather than full removal).

6.1.3 Stakeholder feedback

For each option, any relevant feedback obtained from stakeholders at any part of the stakeholder engagement process was used within the final assessment. The information covered a range of aspects, but was typically used to identify reaches with sympathetic land owners or where there was potential to link up with other initiatives or existing restoration work.

6.1.4 Benefit to local morphology

As discussed above, the scoring of options based on their capacity released, introduced bias because of the influence of water body length on scores. In order to account for this, the factor of local morphological benefit was considered. The benefit to local morphology was calculated as total capacity released by the option multiplied by water body length. Options were then grouped into one of five classes based on these values.

It is recommended that in future studies of this nature, the scores for local morphological benefit are incorporated into the MCA, rather than being incorporated at this stage.

6.2 PRIORITISATION METHOD

An expert judgement approach was used to assess options in terms of the various factors outlined above, as well as the MCA score, in order to come up with a final ranking. The ranking that resulted from the MCA was only changed where the additional factors were deemed to outweigh any difference in MCA score between candidate restoration options. This typically occurred where two or more options had MCA scores within one or two points but greater relative differences in estimated cost, local morphological benefit or stakeholder support. For example, where two options were separated by one MCA point, but the lower ranked option had a significantly lower estimated cost, this option would be moved above the initially higher ranked option (assuming other factors under consideration were similar).

It is recognised that this approach contains an element of subjectivity. In order to maintain transparency, the information used within the final prioritisation is provided in Appendix H.

6.3 OUTCOME OF FINAL ASSESSMENT

A table indicating the additional factors assessed for each of the options is shown in Appendix H. Some options have been completely ruled out because they are considered unfeasible (generally in relation to existing infrastructure). In consideration of both the MCA score, and the additional factors, the ten options that are most favourable are shown in Table 6.2 and Figure 6.1. Reach summary sheets, which provide more information about each of these options, are found in Appendix I. The top ten options are those which will provide the greatest (morphological/ NFM/ environmental/ socio-economic) benefit, as well as having favourable conditions for implementation.

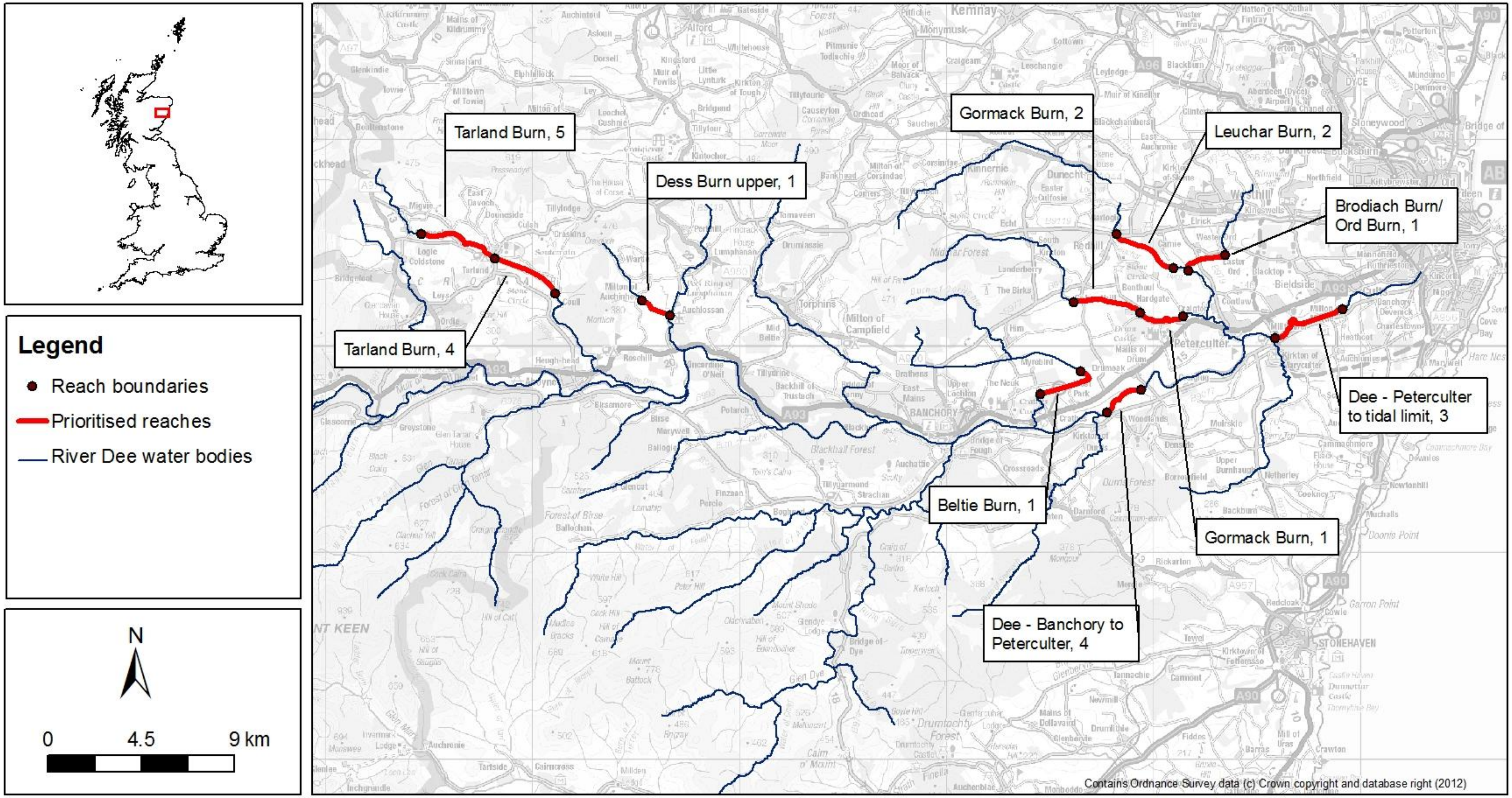
The ranking given here provides a starting point for determining which options to take forward. However, options that do not fall into the top ten should not be completely ruled out. It was not within the scope of this study to take all site specific factors into account, including potential impact on fisheries, which is likely to be significant for certain options. There are likely to be other, currently unknown factors that may influence the implementation of options. These factors may become apparent when options are taken forward to more detailed appraisal/ design and may alter the degree of favourability of certain options.

A further factor that was not considered in the ranking was the relative locations of options. From an ecological and physical process perspective, there is likely to be a disproportionately greater benefit attained from restoring several adjacent reaches, compared with restoring single reaches dispersed through the catchment. By restoring several adjacent reaches, system functioning at larger scales will be addressed, which will enhance recovery at the reach scale, thus providing greater overall benefit. Depending on the priorities for restoration outcomes, it may be prudent to select a lower ranked reach for restoration if it adjoins another reach that has also been selected, allowing continuous restoration of a longer length of river.

Table 6.2 Summary of top ten reaches prioritised in final assessment, ordered 1-10

Water body ID	Water body name	Reach no	Reach location	MCA score	Cost factors	Other factors considered
23315	Dee - Peterculter to tidal limit	3	Milltimber to Ardoe House Hotel	73	• Cost band 5, however, costs are low in relation to benefits; • Option may need modification to avoid critical infrastructure; • Moderate value land: highest LCA value in reach is 3.2.	• High local morphology benefit
23321	Leuchar Burn	2	Garlogie to Broadwater	60	• Cost band 4, low cost in relation to benefits • Moderate value land: highest LCA value in reach is 3.2	• Moderate local morphology benefit • Potential to link with potential scheme for removal of Garlogie dam and modification of Loch of Skene weir
23338	Tarland Burn	4	Tarland to Bridgend Steading	41	• Cost band 4, moderately low cost in relation to benefits • Moderate value land: highest LCA value in reach is 3.2	• Moderate local morphology benefit • Re-meandering previously scoped at site • Dredging likely to occur over summer
23322	Brodiach Burn / Ord Burn	1	Downstream Easter Ord Farm	39	• Cost band 3, costs are low in relation to benefits; • Moderate value land: highest LCA value in reach is 3.2	• Moderately low local morphology benefit
23316	Dee – Banchory to Peterculter	4	Park House	40	• Cost band 4, costs are moderately low in relation to benefits • Moderate value land: highest LCA value in reach is 3.1	• Low local morphology benefit
23320	Gormack Burn	2	Milton of Cullerlie to Blackhall	34	• Cost band 4, costs are moderate in relation to benefits; • Moderate value land: highest LCA value in reach is 3.2	• Moderately high local morphology benefit
23337	Dess Burn - upper	1	Downstream Mill Farm	32	• Cost band 3, costs are moderately low in relation to benefits • Moderate value land: highest LCA value in reach is 3.2	• Moderately low local morphology benefit • RSPB proposed wetland site nearby
23324	Bo Burn	2	Loch of Park to Coy bridge	30	• Cost band 4, costs are moderate in relation to benefits; • Moderate value land: highest LCA value in reach is 3.2.	• Moderately low local morphology benefit

Water body ID	Water body name	Reach no	Reach location	MCA score	Cost factors	Other factors considered
23338	Tarland Burn	5	Hopeswell to Tarland	30	• Cost band 4, costs are moderate in relation to benefits; • Moderate value land: highest LCA value in reach is 3.1. • Option may need modification to avoid critical infrastructure;	• Moderately low local morphology benefit • Ongoing discussions between JHI / Aberdeenshire Council and landowner • Community wetland adjacent – possibility to extend
23320	Gormack Burn	1	Blackhall to Mid-Anguston	30	• Cost band 4, costs are moderate in relation to benefits; • Option may need modification to avoid critical infrastructure; • Moderate value land: highest LCA value in reach is 3.2.	• Moderate local morphology benefit



Notes:	cbec	*River Dee Restoration* **Top ten reaches prioritised following final assessment**		
		Project No. U13-1008	Created By: GK	**Figure 6.1**

7. SUMMARY AND RECOMMENDATIONS

This report documents the development and application of a new approach to catchment-scale restoration assessment, which aims to identify measures that can address multiple issues, specifically morphological restoration and natural flood management. Given that this is a pilot study, this section first summarises the principal outcomes of the assessment, before providing a critique of the adopted methodology. It is intended that the critique will allow the methods to be refined and developed into an approach that can be applied to other catchments in Scotland.

7.1 SUMMARY OF FINDINGS

7.1.1 Geomorphological

Assessment of morphological restoration opportunities was carried out using the MImAS methodology because of its direct link to WFD status for morphology. Key findings of this element of the work include:

- Realignment is a very widespread pressure within all of the study water bodies except for the lower Feugh and the main stem Dee between Banchory and Peterculter. Embankments are found in most studied water bodies and are a particularly prevalent pressure on the Dee main stem downstream of Peterculter, as well as on Tarland and Beltie Burns and the upper section of the lower Feugh water body. Hard bank protection is also widespread in several water bodies.
- These pressures are likely to have a significant impact on sediment erosion, transport and storage processes in these channels and on their ability to interact laterally with their floodplains (not explicitly considered in the MImAS-based assessment).
- The option that released the greatest capacity was full restoration on the Dee between Milltimber and Ardoe House Hotel. Other high scoring options were found in the upper Dess Burn, the Brodiach/Ord Burn, the Leuchar Burn and the Dess/Lumphanan Burn. All of these options included embankment removal and mitigation of high impact realignment.
- It is recommended that further geomorphic assessment be carried out in order to ensure that options taken forward are physically appropriate at both the system scale and the reach scale. This is discussed in Section 2.6. Geomorphic assessment of three water bodies is provided in Appendix D. It is recommended that an equivalent level of assessment should be carried out for all water bodies to allow appraisal of all options in relation to system scale geomorphic process.

7.1.2 Hydrological

A catchment scale hydrological model was used to investigate the potential for modifications to floodplains and to flow generation area land cover/ drainage to reduce flood risk within the Dee catchment. Key findings were as follows:

- When modifications to floodplains were considered (e.g. embankment removal and channel realignment), the water body with by far the greatest absolute and percentage reduction in flood peak was the Dee main stem from Peterculter to tidal limit. Measures in reach 5 within this water body had the greatest effect on flood peak attenuation, with embankment removal and re-meandering resulting in increased potential for floodplain storage.

- The Tarland and Gormack Burns have the second and third highest percentage reduction in flood peak. In the Tarland Burn NFM measures in reach 7 were the most effective, while in the Gormack Burn reaches 5 and 6 were the most effective. These are straightened reaches with potential for realignment (meandering) and floodplain reconnection.
- When out-of-floodplain measures were considered, re-naturalisation of land cover and drainage characteristics in the Brodiach/Ord Burn sub-catchment was predicted to result in the greatest local impact to flows, with a reduction of 16.7%. This, sub-catchment together with the other top water bodies, is dominated by improved grassland land use. This indicates that altering the land management practices of large areas of improved grassland, particularly in these water bodies, is likely to have the greatest effect on reduction of flood peaks.
- Even when undertaken at the scale of a water body, or the whole catchment, land use changes are unlikely to result in a significant reduction in flood peaks at the catchment scale.
- A more detailed hydrological model is needed to properly address the issues of how re-naturalisation of land use/ drainage in flow generation areas affects hydrograph characteristics, particularly those relating to flood peak de-synchronisation.

7.1.3 Multi-criteria analysis and subsequent assessment

The MCA provided a transparent means of scoring and assessing the multiple benefits of each option, allowing an overall score to be determined, which could then be used to assess the combined merits of each option relative to others. Further information relating to costs, constraints, further benefits and opportunities was used, in conjunction with the MCA score, to undertake a final assessment and prioritisation of options. The top option overall was restoration of the Dee between Milltimber and Ardoe House Hotel. This option scored highest for NFM benefit and also results in the greatest improvement to MImAS capacity released, making it the most favourable option overall by a large degree, even when factors such as cost and surrounding land use were taken into account. However, full implementation may be prevented by the presence of critical infrastructure in the reach. Other high scoring options included restoration of the Leuchar Burn from Garlogie to Broadwater (potential to increase water body status to good) and restoration of the Tarland Burn from Tarland to Bridgend Steading (high potential benefit to NFM).

7.2 ASSESSMENT OF THE METHODOLOGY

7.2.1 Morphological assessment

The morphological assessment was intended to identify physical pressures within the catchment and develop a catchment scale restoration strategy to address these. However, the ultimate aim of the assessment was to determine where works could be carried out that would improve the status of a water body for morphology under the WFD. As such, the assessment was entirely based around the MImAS classification scheme since this is the methodology used to determine the morphological status of water bodies in Scotland. Some of the limitations of using MImAS to develop a catchment-scale morphological restoration strategy have been discussed already (Sections 2.5.3 and 2.6) and are reiterated here.

MImAS assigns scores to morphological pressures, based on their ‘hazard rating’ (which is not site-specific), in order to calculate the total capacity used within each water body. This then determines the water body's status for morphology, with a lower capacity used leading to a more favourable status class. If morphological restoration is simply seen as measures to improve WFD status for morphology then it will be focused on removing pressures that have the greatest impact on MImAS capacity used within a water body, as has been the case in this study (following guidance from SEPA). MImAS provides a convenient, quantitative measure of morphological improvement (although its underpinnings are based in subjective assessments) associated with restoration options, which has the appearance of being transparent and is simple to feed into the MCA. However, there are limitations to the quantification of morphological pressures in MImAS (discussed to some extent in Section 2.6), such that reliance purely on this methodology does not allow the development of a fully process-based restoration strategy.

Under the MImAS-based approach, the specific impacts to geomorphic process from a particular pressure are not assessed. The likely degree of impact is implicitly assumed from the calculated capacity used. No consideration, beyond reach type classification, is given to geomorphic process. This makes it impossible to determine the locations where restoration will have the greatest benefit to process or to determine geomorphically appropriate solutions for an impacted reach (e.g. restoration of a more natural sediment supply regime by removing bank protection).

It is recommended that a more appropriate approach to generating a catchment-scale, process-based restoration plan would be to follow the standard fluvial audit approach (which has proved to be successful in many previous studies), perhaps in conjunction with a regulatory-influenced MImAS-based assessment. The fluvial audit-based approach is used to gain an understanding of geomorphic process at the catchment scale, using quantitative data to determine the sediment transport regime within the catchment. Data collected as part of the fluvial audit are then used to identify the significant impacts to morphological process across the system. The use of historical mapping data or 'reference' reaches helps to identify changes that have occurred as a result of human pressures. Once these impacts are known, options to restore geomorphic process can be developed. The strong process-based foundation of the approach allows for a high degree of confidence that recommended actions will achieve the desired effects at the local scale.

It is recommended that in future studies a process-based fluvial audit type assessment should form a significant part of the appraisal of morphological restoration options (perhaps in tandem with MImAS) and should contribute to scores of options within the MCA.

7.2.2 NFM assessment

The need for identification and assessment of NFM measures at the catchment scale in this study led to the development of a relatively simple, high-level approach based on a catchment-scale hydrological routing model. The benefit of this approach was the ability to score measures in water bodies and reaches in terms of their relative benefits to NFM throughout the entire ~2,200 km^2 of the Dee catchment. This allowed a ranking of the options that could feed into the MCA. However, as discussed in Section 3.2.3, there is a very low degree of confidence in the absolute values of flow attenuation. As such, the results are of limited value for determining the actual benefit to vulnerable areas or for assessing the benefits of the measures relative to other flood management measures.

Additional, more detailed hydraulic modelling at sites where favourable measures have been identified is recommended in order to provide greater understanding of the absolute NFM benefit. More detailed modelling is also recommended in situations where more than one NFM measure is to be implemented, in order to understand how the measures interact to influence the degree of flood attenuation downstream.

It was noted in the assessment that the routing model predicted that some measures would result in an increase in flooding, probably because of flood peak synchronisation. While it is acknowledged that the actual values output cannot be determined with certainty from the level of modeling undertaken, these results suggest that there is potential for NFM measures to have the opposite effect to that intended if implemented inappropriately. This gives a further reason to support the need for further, more detailed modelling of options.

The assessment of out-of-floodplain NFM measures (i.e. re-naturalisation of flow generation area land use/ drainage) was limited by the current lack of a recognised method that could be implemented within the time and resource constraints of the project (a distributed catchment-scale hydrological model would allow a more detailed assessment with a greater physical basis, but is extremely data-intensive and time consuming to set up and run). The alteration of catchment descriptors within the ReFH model, to alter the flows generated, was used as a proxy for land use change. This allowed for differentiation between sub-catchments in terms of the likely contribution of land cover/ drainage change to NFM. However, it should be recognised that site-specific factors, which may have a significant effect on the response of flows in an individual sub-catchment to land use change, are not accounted for by the method.

7.2.3 Integration of morphological and NFM options

In terms of its general approach, it is considered that the MCA process is as robust as any method can be to determine the relative effects of disparate factors on the prioritisation of restoration options. The specific approach taken in this project, based on the guidance from SEPA, was to investigate morphological restoration and NFM options separately and then integrate the two sets of measures to determine where opportunities for multiple benefits exist, with equal weighting given to NFM and morphology.

One issue with this approach was the mismatch in appropriate scales of assessment between the two types of measures. NFM measures typically must be implemented over a large spatial scale in order to have a measurable benefit to flood hydrograph attenuation. Morphological restoration is generally implemented at smaller spatial scales because of the scale at which pressures typically occur and the high costs associated with large-scale restoration. In addition, the differences in the nature of benefits and methods for quantifying these between the two types of measures makes it very difficult to directly compare them against each other (i.e. what degree of morphological improvement and predicted flood risk reduction would be considered equal in terms of benefits?). In this study scores for the two types of measure have been scaled relative to the maximum and minimum scores identified within the catchment. However, if applied more widely, this approach does not allow for a consistent scoring of options between catchments. The scores for morphology and NFM are calculated relative to the overall potential for morphological restoration and NFM within the Dee catchment and this is likely to vary greatly between catchments.

In theory, the approach of giving equal weighting to NFM and morphology objectives may result in the prioritisation of options that, while giving a high combined score, do not represent a particularly beneficial option for either NFM or morphology individually. In particular, this approach is not appropriate to the planning of NFM. Measures to benefit NFM should ideally not be chosen partly on the weighting of WFD benefit, but on optimal benefit to flood risk.

Based on the experience of undertaking this study, we suggest that a better approach would be to focus on either NFM or morphological restoration as the primary objective, with the other type of measure assessed as a secondary benefit. Initial assessment would be based purely on the primary objective, to determine a ranked set of options. Assessment of secondary benefits could then be focused on these locations, to allow differentiation between options that were very similar in terms of their benefit to the primary objective. This would allow for a more targeted and efficient approach, and a more robust scoring system. It is recognised that the focus of any future studies of this nature would be dependent on policy drivers and strategic management decisions.

In most of the morphological restoration and NFM options assessed in this study, the spatial extent of the option is an important factor in determining the level of benefit it would deliver. The nature of pressures within a catchment is such that options necessarily range in spatial scale. In cases where the linear extent of continuous pressures was considered too long to be addressed within a single restoration action, the section was broken into two or more restoration reaches, in some cases quite arbitrarily. The MCA scoring system used gives a bias towards large-scale options because of their greater potential benefits. However, these large-scale options are more likely to be very costly and logistically difficult to implement as a whole.

7.2.4 Stakeholder engagement process

7.2.4.1 Liaison with existing catchment partnership

The extensive history of stakeholder engagement on the River Dee has been both a positive and a negative for this project. The presence of an existing partnership which can be used to contact a wide range of stakeholders and to facilitate a flow of information has been a help in ensuring that stakeholders are aware of the project. However, many stakeholders feel they have been ‘over-consulted’ and want to see action on the ground, rather than considering further potential sites. The variety of previous projects in the catchment also means that there are few ‘new’ sites and most sites have some history of past stakeholder engagement and discussion. This means that approaches to landowners need to be made with an awareness of previous discussions and it is important to tailor approaches more carefully than in a catchment with little or no previous stakeholder engagement.

7.2.4.2 Stakeholder workshop

This appeared to be an effective use of time and was positively received by most attendees. Given the diversity of projects within the Dee catchment, there is a very real risk of ‘treading on toes’ by approaching landowners directly, without awareness of previous interactions. It is therefore important that the views of stakeholders expressed at this meeting are respected. Approaches to landowners should not be made without consultation with relevant stakeholders first and if necessary, a ‘proxy’ approach via an existing stakeholder should be used.

The workshop also provided a useful opportunity to outline the approach being taken by SEPA within the pilot catchments. Most participants seemed to accept that SEPA requires some form of ‘audit trail’ to demonstrate how sites were selected. However, the precise process that was used to select sites was of less interest to stakeholders, who felt that landowner buy-in and potential delivery mechanisms would ultimately have the greatest impact on which sites were selected. Again, this reasonably pragmatic response should be respected – if stakeholders have only limited interest in the process and are more interested in outputs on the ground, this should be accepted. To some extent, stakeholders in the Dee are likely to be most interested in the final presentation from the project, where steps to implementation can be outlined. This 'outcome focus' is a result of the past stakeholder discussions which have taken place in the Dee in the past and is important that future stages of the pilot catchment project recognise this difference between catchments.

7.2.4.3 Landowner engagement

As stated throughout the project, contacting landowners with information about the project prior to survey work would have been a more courteous and appropriate approach. The lack of address data was a significant negative in the development of the project, both in terms of increasing the amount of time required to deliver the project and in reducing the effectiveness of communication. It is strongly recommended that efforts are made to establish a mechanism by which address data can be made available for legitimate project uses. Any other communication method is at best piecemeal (for example, using the NFUS and SLE organisations, who can only pass information onto their members) and at worst, can appear divisive.

7.2.4.4 Wider awareness raising

The original consultation plan which was prepared by the project team included the production of press releases for the media, focusing particularly on the agricultural sector. However, the client confirmed that they did not wish to issue press releases at this time, and so no interaction with the media took place. Given the difficulties with obtaining address information for land managers, the project team believe press releases would have provided an additional opportunity for land managers to find out about the project and would also have helped to raise awareness with the wider public.

7.2.4.5 Recommendations for future stakeholder communication within the Dee

1. Stakeholders within the Dee are primarily interested in work on the ground and have been extensively consulted in the past. This should be recognised and stakeholder consultation kept to a minimum unless it involves specific actions.
2. Mechanisms for contacting landowners within river reaches should be established, in order that effective, targeted communication can be used where necessary.
3. The large size of the Dee catchment means that stakeholders in some parts of the catchment may be less interested in work happening elsewhere. This should be recognised and where stakeholders chose not to engage with a particular aspect or element of the project, this should be respected.
4. Providing information through local media channels should be undertaken where possible. This provides information to those who are interested / chose to read about the project, but doesn't force stakeholders to take an interest.

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