River Don Scoping Study

Draft Report

Ardhuncart Estate

cbec eco-engineering UK Ltd

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Photo credit: taken by Phillip Whitfield, Tilhill on behalf of the Ardhuncart Estate

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 OVERVIEW

cbec eco-engineering UK Ltd was commissioned by Ardhuncart Estate, Aberdeenshire, to undertake a scoping study to investigate high-level river corridor opportunities along the ~5 km of the River Don that falls within the Estate boundary. The scoping study also covers tributaries of the River Don (including the Mossat Burn and Auld Water) and the wider floodplain areas, where appropriate. The study seeks to identify potential restoration measures that will offer a variety of benefits, including (but not limited to) habitat improvement, natural flood management (NFM) and improvements in biodiversity and ecological connectivity.

Both freshwater restoration (including restoration of natural flows in rural catchments) and habitat/species restoration (focusing on management for enhancement and connectivity) are priority themes for NatureScot's Nature Restoration Fund (NRF). Opportunities identified within this scoping study will focus on these key priority themes. Potential opportunities for freshwater restoration are likely to include NFM and surface water management (e.g. improving channel/floodplain connectivity), river restoration (e.g. realigning/remeandering), improvements to instream and riparian habitat (e.g. riparian woodland creation, addition of large wood to the channel) and enhancing or creating wetlands and other important floodplain habitats. Potential opportunities for habitat/species restoration are likely to overlap considerably with the freshwater opportunities identified, including within the riparian corridor (e.g. extending riparian buffer zones), the floodplain (e.g. creation of new floodplain habitat) and the wider catchment (e.g. changes in land use/management to encourage further species and habitat diversity).

cbec adopts a 'nature-based' approach, working with the river system's natural processes, allowing options to be developed within the context of the physical process regime of the wider catchment. Central to this approach is the premise that consideration of the natural geomorphic processes operating for a given river system allows for the development of a restoration strategy that is appropriate to imposed physical conditions and, where appropriate, permits recovery of the river to a more diverse and self-sustaining condition. In this way, by tackling the causes rather than the symptoms of human-induced pressures, the implementation of river and floodplain restoration options encourages the river system itself to do the work of maintaining a 'natural' and dynamic physical environment, which promotes the self-sustaining evolution of a more natural biota.

1.2 STUDY SITE

The headwaters of the River Don are located around Inchrory (at approximately OS NGR NJ 1922 0901). The watercourse then flows predominantly eastwards towards Aberdeen, where it discharges into the North Sea. A ~5 km section of the River Don, extending from Ordnance Survey National Grid Reference (OS NGR) NJ 47345 16313 to the confluence of the Don with the Mossat Burn at NJ 49109 18508 (Figure 1.1), forms the focus of this Scoping Study. The upstream half of this reach passes through the Ardhuncart Estate near Kildrummy, then flows along the northwestern land boundary for the remainder of the study area. To the north, the Estate is bordered by the Mossat Burn. This ~0.9 km stretch from the confluence upstream (OS NGR NJ 48506 19001 to NJ 49109 18508) will also be considered for river restoration opportunities.

Four tributaries enter the River Don within Ardhuncart Estate: the Culsh Burn, the Auld Water (also known as the Burn of Minfur upstream of the A97), the Ferneybrae Burn and the aforementioned Mossat Burn. This study will focus on the Auld Water and Mossat Burn, which were assessed alongside the River Don during the geomorphic walkover (Section 3).

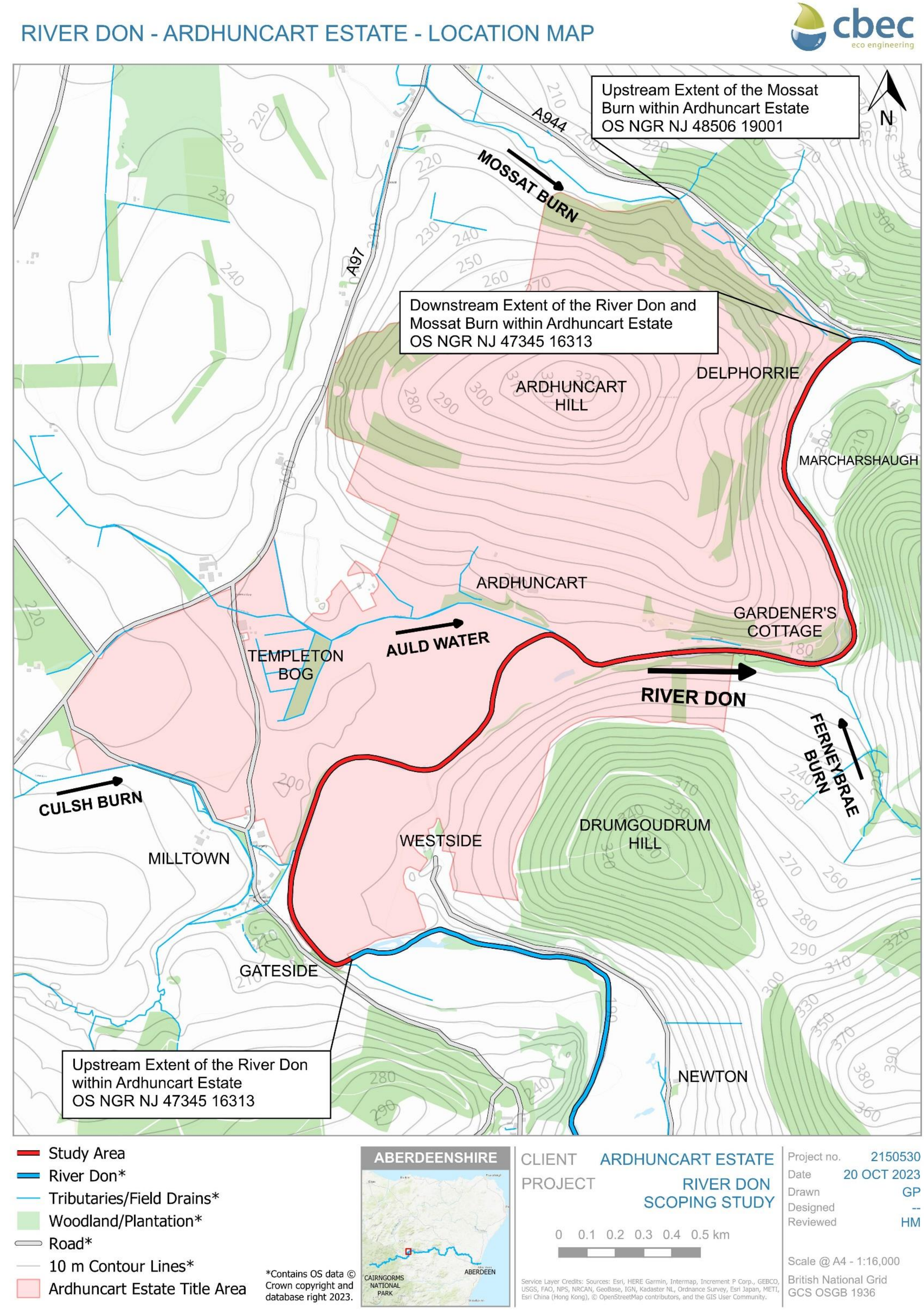

Figure 1.1 Study site location: River Don at Ardhuncart Estate.

2. DESK-BASED ASSESSMENT

A desk-based assessment synthesising all existing and readily available morphological, ecological, archaeological and flood risk management data for the study site has been undertaken. Findings from this desk study were used to infer the natural hydrological and morphological processes at work within the study site and the wider catchment, providing a basis for the identification of geomorphologically appropriate options for the Estate.

Other sources of data relevant to consideration of high-level river management options, such as SEPA's NFM opportunity mapping and a dataset highlighting priority riparian corridor improvement areas (the latter of which was developed through separate studies undertaken by Scottish Forestry and Marine Scotland Science), have also been consulted during this desk study. These priority areas were targeted during the geomorphic walkover to assess the suitability of these locations for the proposed options.

2.1 LAND USE

Land use and land cover patterns within a catchment control the influx of water, sediment and large woody material to the system. In addition to the effects on river processes, an understanding of contemporary land use will aid the identification of options that are compatible with and, where possible, complement existing land management practices. Land use/cover will be assessed for both the reach-scale study site and the wider catchment area that drains into this site.

Hillslope land cover across the catchment is dominated by shrub/heathland vegetation, with raised/blanket bogs and montane vegetation at higher elevations, transitioning to agriculturally dominated land downstream of the Cairngorms National Park's eastern boundary. Areas of woodland (predominantly coniferous) are present throughout the catchment; the river corridor is generally given over to agriculture throughout, except for the headwater reaches, which are covered by heathland. The natural supply of large wood to the River Don is likely to be minimal owing to the relative lack of woodland in the immediate vicinity of the watercourse and the dominance of open land cover types such as shrubland, heathland and blanket bogs.

Around the study reach, land cover is a mix of arable (barley) and pasture (temporary and permanent grassland), with broadleaf woodland and rough grassland also present outwith the farmed areas. Agricultural practices occur primarily within the floodplain. Woodland provides land cover across the steeper hillslopes of Drumgoudrum and Ardhuncart Hills, as well as The Corbouies. Rough grassland was noted within the marginal areas, such as the riparian corridor, typically accompanied by scattered trees. Additionally, artificial drainage indicating an area of waterlogged ground, known as Templeton Bog, is present on the north side of the River Don, feeding into the Auld Water.

Throughout the majority of Ardhuncart Estate, agricultural land use extends up to the riverbank, particularly on the river left (northern) side of the channel, resulting in a limited riparian corridor and potentially contributing to reduced bank stability. Further desk-based assessment of the potential riparian cover and habitat improvements is discussed in Section 2.6.3. Additionally, during the geomorphic assessment, a qualitative assessment of bank erosion will be undertaken to determine if the limited bankside vegetation is impacting bank stability.

2.2 TOPOGRAPHY

Catchment and valley topography influences how rapidly the system responds to rainfall, affects the energy of the resulting flows, and controls the sediment transport regime within the river system. Understanding the Don catchment's terrain, both upstream of and within Ardhuncart Estate, will therefore be essential to identifying river restoration and flood management opportunities that work with natural river processes.

A search of the Scottish Government's Remote Sensing portal concluded that LiDAR data are not available for the site. LiDAR is a remote sensing method for scanning the topography of an area. Here, Ordnance Survey Terrain and contour data were utilised, supplemented with channel geometry measurements taken during the geomorphic walkover and subsequent Geographic Information Systems (GIS; mapping software) analysis, to inform option identification.

2.2.1. River Don

The Don catchment draining to Ardhuncart Estate is dominated in its upper reaches by steep headwater areas within the Cairngorms National Park, where topographically confined channels likely provide a plentiful supply of sediment and flow to the watercourse. The river valley becomes less confined with increasing catchment size, particularly downstream of Inchrory, providing opportunity for lateral migration of the channel as well as the storage and reworking of coarse sediment.

Valley topography within the Ardhuncart Estate begins to exhibit a 'bottleneck' form downstream, influencing the degree of natural channel adjustment and the flood response of the Don. The Don initially flows across a wide floodplain (relative to the remainder of the study site) between Gateside and Ardhuncart Lodge. Downstream of the Lodge to Macharshaugh, valley confinement (topographically) increases, narrowing the floodplain. During flood events, the topography is expected to act like a funnel, concentrating the flow through this narrower section within the downstream half of the Estate.

This hydraulic 'bottleneck' is a natural consequence of the interaction between flood hydrology and the local terrain; therefore, it cannot be entirely mitigated through changes to land management at the affected location. Instead, the principles of NFM should be applied upstream of this point, in order to slow the movement and rate at which water reaches this location. These options may take the form of reducing surface run-off from the surrounding catchment or may act more directly, by improving the connectivity of the River Don to its floodplain to create flood storage that will temporarily hold water and slowly release it back into the channel following flood events. Potential locations for the implementation of NFM measures have been outlined in Section 2.5, derived from high level opportunity modelling undertaken by SEPA. The feasibility of these options will be assessed during the geomorphic walkover.

Additionally, a further study is recommended to identify potential NFM across the River Don catchment, extending beyond the scope of this initial single-Estate-focused assessment. This study could primarily be focused on areas upstream of the Estate, where implementing NFM measures could benefit flood risk within Ardhuncart. It is the cumulative effect of multiple measures being implemented across the catchment that will deliver the greatest benefit for flood risk attenuation for both this bottle-necked area within the Estate and the wider catchment. This option is discussed further within Section 0.

2.2.2. Tributaries

The Auld Water is a minor tributary of the River Don, situated within a low-lying valley. This watercourse flows from its source at ~230 metres above sea level (masl), near Blackbaulk, to its confluence with the River Don at ~190 masl over its ~3.5 km length. The Auld Water is characterised by a gentler bed slope and lower energy than the Mossat Burn. Downstream of Templeton Bog, the watercourse enters the River Don floodplain.

In its upper reaches, the Mossat Burn exhibits a steep channel bed gradient (relative to the Auld Water) as it descends from ~330 masl down to ~250 masl over ~2.5 km of channel length through Glen Laff, a steep-sided valley. Both bed slope and valley confinement reduce dramatically at the bottom of the Glen near Auchmullen. This gentler channel gradient is maintained for ~5.5 km downstream, until the A97 road bridge at ~200 masl. Downstream of the A97 to the Don confluence at Invermossat, the Burn runs between two hills, Ardhuncart and Edinbanchory, which narrow the floodplain once more. The Ardhuncart Estate encompasses ~0.9 km of the Mossat Burn and river right (southern) floodplain within this lower section of the watercourse. This section is well-contained by its topography and the road on the river left side of the valley, which may limit the space available for restoration.

2.3 GEOLOGY AND SOILS

Bedrock, superficial geology/drift and soil cover are important considerations in the development of management options because these factors exercise fundamental controls on sediment availability and the response of the fluvial system to rainfall. Based on consultation of the British Geological Survey's Geology Viewer[1], the upper catchment of the River Don is underlain primarily by metamorphosed sediments dominated by schists and metamorphosed limestones, with some plutonic and extrusive igneous units present locally. In the vicinity of the study area, metamorphosed fine-grained sedimentary rocks including psammites, pelites and semi-pelites form the bedrock underlying Ardhuncart Hill, the eastern valley sides of the River Don, the Mossat Burn and much of the wider floodplain. In contrast, the bedrock underlying the hillslopes to the west of Kildrummy comprises primarily sedimentary rocks such as mudstones, siltstones and sandstones.[2]

The superficial geology of the upper catchment is dominated by alluvial deposits along the river corridor and diamictic till elsewhere, with peat deposits or no superficial cover recorded in upland areas. From Glenkindie downstream, glaciofluvial deposits are increasingly common. These widespread alluvial and glacial deposits provide a source of abundant, erodible coarse sediment. Within the study area, the floodplain superficial deposits are dominated by alluvium, typical of a floodplain that has been reworked through time as a result of natural geomorphic processes related to meander migration. This suggests that the River Don is likely to represent a relatively dynamic river system at this location. Glaciofluvial deposits (gravel, sand, silt and clay of river and/or glacial origin) blanket the western side of the river valley, with the exception of Ardhuncart Hill. Ardhuncart Hill and the eastern valley slopes of the River Don are dominated by till (unsorted material deposited by a glacier). This abundance of coarse sediment (both upstream and within the study reach itself),

[1] https://www.bgs.ac.uk/map-viewers/bgs-geology-viewer/

[2] Sedimentary bedrocks present: Carlinden Shale Formation (Mudstone and Siltstone) and Tillybrachty Sandstone Formation (Sandstone).

combined with the meandering planform of the Don at this stage along its course, suggests that alluvial bar forms (i.e. depositional features on the channel bed) would be expected throughout this reach.

Based on the Scottish Government's 'Scotland's soils' map,[3] soils in the River Don catchment to the Mossat Burn confluence, at the downstream end of Ardhuncart Estate, are predominantly humus-iron podzols and brown earth at lower elevations, with peaty gleyed podzols on steeper slopes and dystrophic blanket peat at highest elevations. Between Glenkindie and Ardhuncart Lodge, the floodplain is comprised of mineral alluvial and peaty alluvial soils. This alluvial soil is absent from Ardhuncart Lodge to Auchentoul, near Bridge of Alford, likely due to the increased valley confinement within this section, limiting channel adjustment and deposition of material within the narrow floodplain.

2.4 HISTORICAL CHANNEL ADJUSTMENT

Analysis of historical datasets, such as previous versions of Ordnance Survey maps, photos and aerial imagery, adds valuable context to the data collected during the geomorphic walkover (Section 3). Such analysis allows evaluation of historical changes in channel planform along the river as the basis for assessing (a) the degree of dynamic behaviour resulting from natural fluvial processes, as opposed to human activity, and (b) the 'reference state' of the river system. A review of the National Library for Scotland's historical map archive[4] and available aerial imagery was undertaken to provide historical context, including identifying historical channel adjustment and past management practices that may have influenced the supply, transport and storage of water and sediment throughout the catchment.

2.4.1. River Don

Ordnance Survey mapping from the late 1800s demonstrates that lateral adjustments of the River Don across its floodplain have been limited by extensive impacts positioned at the top of the channel bank throughout the majority of the Estate.[5&6] Construction of these embankments is likely to have been for flood protection and to provide vehicular access to the adjacent agricultural land. Comparisons of this late 19th century map with present-day OS 1:25,000 scale mapping shows signs of localised planform adjustment around the outer bank of meander bends, where erosion is naturally expected to occur, during this ~150-year period. The Roy Highlands mapping[7] from the mid-1700s illustrates the River Don following a similar course to its present-day position. This 16th-

[3] Scottish Government. Scotland's Soils [Online]. Last accessed 24.11.23 via https://map.environment.gov.scot/Soil_maps/?layer=1

[4] National Library of Scotland Map Images, Georeferenced Maps [Online]. Last accessed 24.11.23 via https://maps.nls.uk/

[5] National Library of Scotland Map Images, Ordnance Survey, Surveyed 1866-68, Published 1870, Aberdeenshire: Sheet LI and LXI, Six Inch Scale. [Online]. Last accessed 05.09.23 via https://maps.nls.uk/view/74425403 and https://maps.nls.uk/view/74425412

[6] National Library of Scotland Map Images, Ordnance Survey, Surveyed 1863-67, Revised 1894, Published 1896, Sheet 76 - Inverurie, One Inch Scale. [Online]. Last accessed 05.09.23 via https://maps.nls.uk/view/74490564

[7] National Library of Scotland Map Images, Roy Miltary Survey of Scotland: Roy Highlands, Surveyed 1747-55 [Online]. Last accessed 05.09.23 via https://maps.nls.uk/roy/#:~:text=The%20Roy%20Military%20Survey%20of,an%20era%20of%20rapid%20change.

century mapping was undertaken at a coarse scale; accordingly, it cannot provide accurate information about channel form or location, but nevertheless provides a qualitative indicator of large-scale geomorphic character and enables the inference of impacts of subsequent channel modifications.

The bridge connecting Kildrummy with Westside (OS NGR NJ 47610 16979) was historically positioned at OS NGR NJ 47766 17085, approximately 200 m downstream of its current position. Other infrastructural alterations to the River Don include five ford crossings that were present at points throughout the Estate in the late 1800s, but are no longer indicated on present-day Ordnance Survey mapping. Whilst necessary to facilitate access, stabilisation of the channel bed within the locality of a ford can limit the degree of channel adjustment and hinder natural processes of sediment transport within the vicinity of these features. Therefore, the removal of these features will have benefited the longitudinal (upstream to downstream) connectivity of geomorphic processes within the Don.

A sawmill was present on the river right bank of the River Don in the late 1800s, just upstream of the southern Estate boundary (OS NGR NJ 47674 16404). Since its decommission and removal, increased morphological complexity is visible within this section of the river, with the channel evolving from a single island upstream of the mill to a series of islands and barforms extending from the southwestern side of Drumgoudrum Hill to Cleek-Him-In pot pools. Present-day aerial imagery illustrates a distinct lack of sediment storage within the remainder of the Don that flows through the Estate, with the exception of the island and associated bar features just upstream of the Gardener's Cottage. Opportunities to enhance in-channel sediment storage and further diversify channel bed morphology will thus be considered during the geomorphic assessment of the River Don.

2.4.2. Tributaries

The Auld Water is indicated to have remained in the same position and with a straightened channel planform since the earliest Ordnance Survey mapping of the area that is available from the National Library of Scotland archives.[5] Drainage channels are also indicated at Templeton Bog in these early maps. It can therefore be concluded that the straightening of this tributary and the Templeton land drainage works occurred prior to the 1870s. The Roy Highlands mapping[8], produced in the mid-1700s, indicates that the Auld Water presented a more sinuous planform throughout its length at this time. This coarse-scale mapping indicates that the pre-realignment Auld Water would have followed a meandering course to the River Don. Opportunities to restore natural channel form and function to the Auld Water will be assessed as part of the geomorphic walkover.

The Mossat Burn displays a slightly sinuous planform between the Mossat Bridge and the confluence with the River Don. Comparison of late-1800s and present-day Ordnance Survey mapping indicates some minor adjustment in the channel planform, typical of a meandering planform.[5] This observation indicates that the Burn presents potential for an 'assisted recovery' river restoration approach, whereby measures such as large wood structures (Section 4.1.6) are installed to enhance the geomorphic processes that are already evident from the observed planform adjustment. This type of restoration aims to help the channel to overcome constraints posed by historic management, for example the milling industry, and undergo natural readjustment towards a healthier and more diverse system.

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[8] Roy Highlands, 1747-52

The past presence of the milling industry within the lower Mossat is evident in the form of two lades, between Howmill and Invermossat; sections of these artificial channels are still visible on present-day aerial imagery. These locations will be visited during the geomorphic walkover to assess the potential for naturalisation of these side channels and to increase habitat provision within this section of the Burn. Associated with these lades, two sluice gates, a ford and a weir were indicated within this section of the Burn on mapping dating from the 1870s.[5] To facilitate natural recovery of a watercourse, removal of all disused infrastructure is recommended wherever practicable to reduce constraints to natural geomorphic process. Further discussion of opportunities to improve the Mossat Burn is provided in Section 4.2.

2.5 FLOOD MANAGEMENT

2.5.1. <u>Flood Risk</u>

The primary source of flooding to the Ardhuncart Estate is fluvial, deriving from the River Don. Flood extents within the Estate are largely defined by the valley topography, such that the spatial extent of floodplain inundation is greater in the upstream (i.e. southern) half of the Estate, where the valley floor is wider (Figure 2.1). SEPA flood maps indicate that the flood water of the River Don and Auld Water combine within the river left (western) floodplain of the Don. Opportunities to enhance storage of water in these areas of floodplain inundation will be considered during the geomorphic walkover, to slow the movement of water through the catchment during flood events.

Flood extents for the lower Mossat Burn indicate that the channel is confined to a relatively narrow valley, within which it is well connected to the floodplain. Slowing the movement of water through this tributary to the Don, through in-channel and floodplain restoration measures, may help to attenuate the flood peak for areas downstream of the Estate.

During the geomorphic walkover (Section 3), NFM and river restoration measures that could help to alleviate flooding within the Estate, as well as potentially benefiting settlements further downstream within the Don catchment, will be assessed.

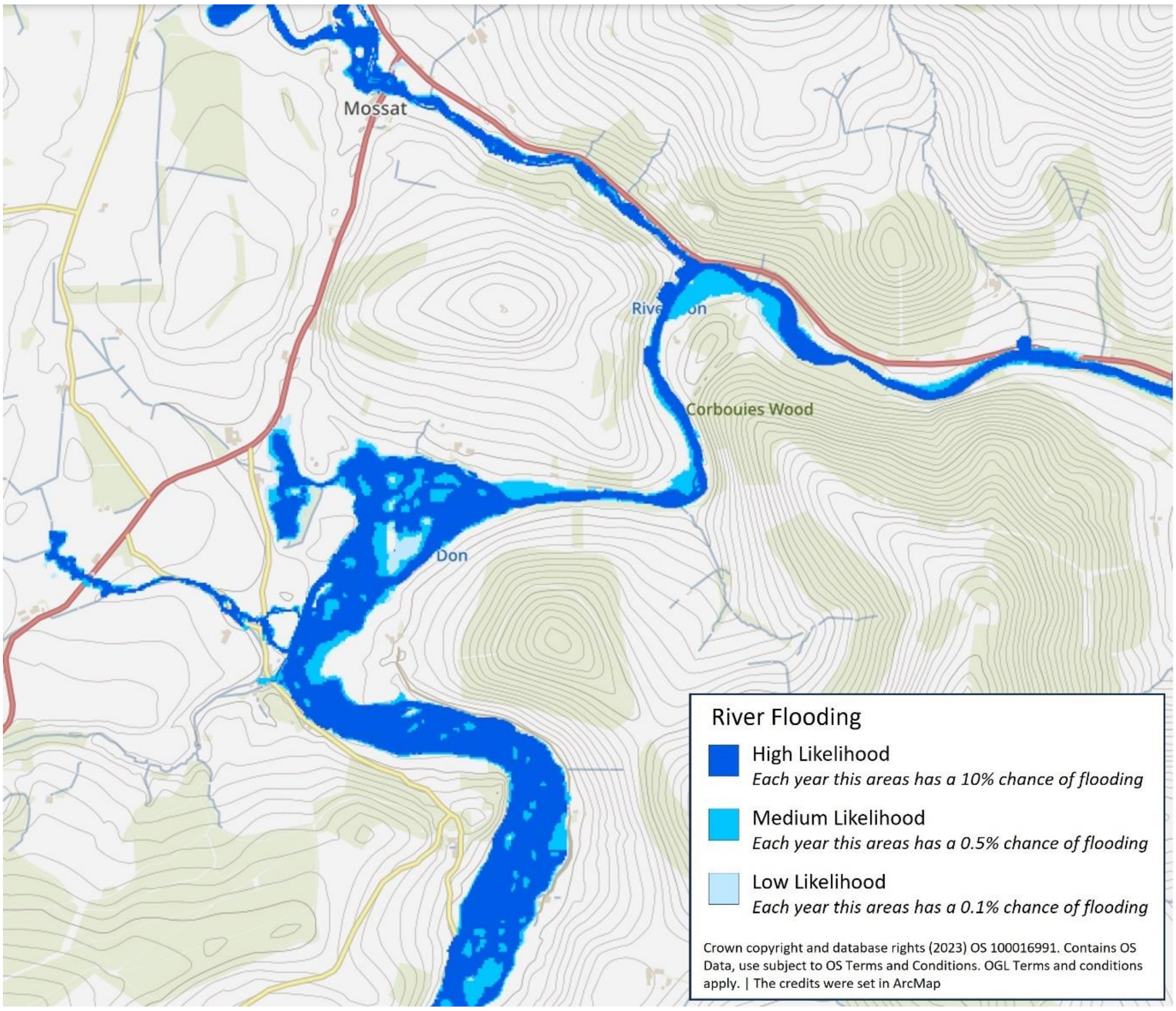

Figure 2.1 SEPA flood risk mapping for the Ardhuncart Estate

2.5.2. Flood Management Issues Identified by the Landowner

Discussions undertaken during an on-site meeting on 12th September and in subsequent email correspondence with the landowner have highlighted a number of key issues in regards to flooding within the Estate boundary. In particular, flood risk for a number of key flood receptors within the Estate is becoming of increasing concern, with regular flooding of the Estate access road, the tennis courts and the workshops around Gardener's Cottage. Concerns were also noted regarding the bridge crossing just upstream of Delphorrie, which takes the access road to Brux and Macharshaugh. The landowner indicated that an embankment has been breached repeatedly downstream of Kildrummy, resulting in more frequent inundation of the floodplain to the north; erosion around this meander bend is also threatening an access road along the river left (i.e. western) bank upstream of the embankment breach. Early discussions have indicated that the landowner would be amenable to potential options to formalise this breach and encourage greater flood storage here.

The options developed as part of this scoping study will seek to address these concerns where possible, by providing NFM benefits that could help ease flood risk at the areas of specific concern. NFM is a collective term for a series of nature-based solutions that seek to slow the movement of water through a river catchment, with the central aim of attenuating the flood peak. These collective techniques focus on improvements to land management practices, land cover and restoring natural river processes within tributaries and the wider catchment (particularly the upper catchment) to alleviate flood risk to areas further downstream. It is widely accepted that it is the cumulative effect of multiple NFM measures spread across the catchment that can provide the greatest benefit in terms of flood peak attenuation. Accordingly, it is recognised that flood risk at this location is also affected by land use and management across the wider catchment draining to the Estate and that a more strategic catchment-wide approach to restoration and NFM is likely to yield much greater benefits than reach-based restoration. Nevertheless, the options developed as part of this study will seek to maximise possible NFM and habitat benefits within the current scope and will provide a template for future restoration work across the catchment.

2.5.3. <u>SEPA Natural Flood Management Opportunities</u>

A preliminary review of the Scottish Environment Protection Agency's (SEPA's) online NFM opportunity maps was undertaken as part of this desk study. Consideration of these opportunities was combined with analysis of aerial imagery as well as current and historical OS mapping to gain an initial understanding of target areas which present potential for implementing NFM measures across the River Don study site. This information was used to improve efficiency during field surveys, highlighting key areas within which ground-truthing for restoration and NFM opportunities would be best targeted.

SEPA's NFM opportunities maps were developed using remotely sensed data as part of a national screening process, to identify areas where different approaches to reduce flood risk could be employed. For fluvial systems, flood management maps were produced to look specifically at run-off generation, sediment management and floodplain storage[9]. This dataset was used to determine any potential areas where restoration measures could deliver additional flood management benefits to the Don catchment.

NFM Opportunities within Ardhuncart Estate

A review of the opportunity maps for this section of the River Don indicated medium potential for floodplain storage between the upstream Estate boundary and Ardhuncart Lodge. The floodplain adjacent to the Auld Water (also known as the Burn of Minfur, upstream of Kildrummy) is indicated as having high flood water storage potential, particularly on the southern side of the watercourse between Bear Lodge and the Don confluence.

The NFM opportunity mapping also assesses the potential for sediment management throughout the River Don. This high-level assessment considers channel bed slope and assumes sediment supply from upstream to determine whether an individual reach is dominated by sedimentary processes of erosion, transport, or deposition. Upstream of the site to the confluence with the unnamed tributary at Milltown, the channel has been classed as 'Moderate Erosion', increasing to 'High Erosion' downstream to Ardhuncart Lodge. 'Moderate Deposition' dominates from Ardhuncart Lodge to Gardeners Cottage, with a 'Moderate Erosion' classification again further downstream. This transition to deposition-dominated could indicate a reduction in channel bed gradient. The Mossat Burn is dominated by alternating sections indicated to exhibit moderate erosion and deposition.

Run-off reduction opportunities within the study area were limited to the southern hillslope of Drumgoudrum Hill and the eastern valley side of the Ferneybrae Burn. Contour lines in these areas

[9] Further information on how these maps were developed can be obtained from SEPA's (2013) report, 'Identifying Opportunities for Natural Flood Management'.

indicate a steeper gradient relative to the remainder of the land adjacent to the Don in this section of the catchment. Increasing ground surface roughness across these slopes, for example by enhancing vegetation cover through tree planting, could contribute to a reduction in flood risk by slowing the rate at which water drains from the surrounding land into the watercourse network. The Corbouies are also characterised by steep hillslopes; however, this area has likely not been highlighted as a run-off reduction potential area given that it is already wooded.

Downstream of Ardhuncart Lodge, the River Don floodplain becomes constricted, with an average floodplain width of 100−200 m. Narrowing of the valley within this section means that any run-off from the surrounding hillslopes will be delivered directly to the watercourse, with less surface area for infiltration into the floodplain (i.e. relative to the upstream half of the site). Therefore, prioritising riparian buffer strips along the banks of the Don within this section could further enhance run-off reduction. Such measures could also be implemented on the Ferneybrae Burn and Mossat Burn.

During the geomorphic walkover (Section 3) the feasibility of these NFM opportunities will be ground-truthed and potential to add further river restoration benefit to these management areas will be assessed.

NFM Opportunities within the Upper Catchment of the River Don

A high-level review of NFM opportunities proposed within the upper Don catchment draining to Ardhuncart Estate was undertaken to provide an overview of options that may alleviate flooding within the Estate. A more detailed assessment of these opportunities is outwith the scope of this reach-scale assessment of opportunities within Ardhuncart Estate. However, these opportunities should be explored in more detail through a catchment-scale study; further details regarding this recommended assessment are provided in Section 0.

Upstream of Glenkindie, the floodplain becomes much narrower limiting opportunities for floodplain storage in the upper catchment. The steepness of the upper catchment suggests that run-off reduction, including afforestation of the riparian corridor, hillslopes and the wider catchment, as well as drainage ditch blocking would likely offer the greatest benefit (i.e. relative to other NFM measures) within the part of the Don catchment. Between Glenkindie and Ardhuncart, where the valley topography widens, opportunities for floodplain storage are identified within the SEPA NFM mapping.

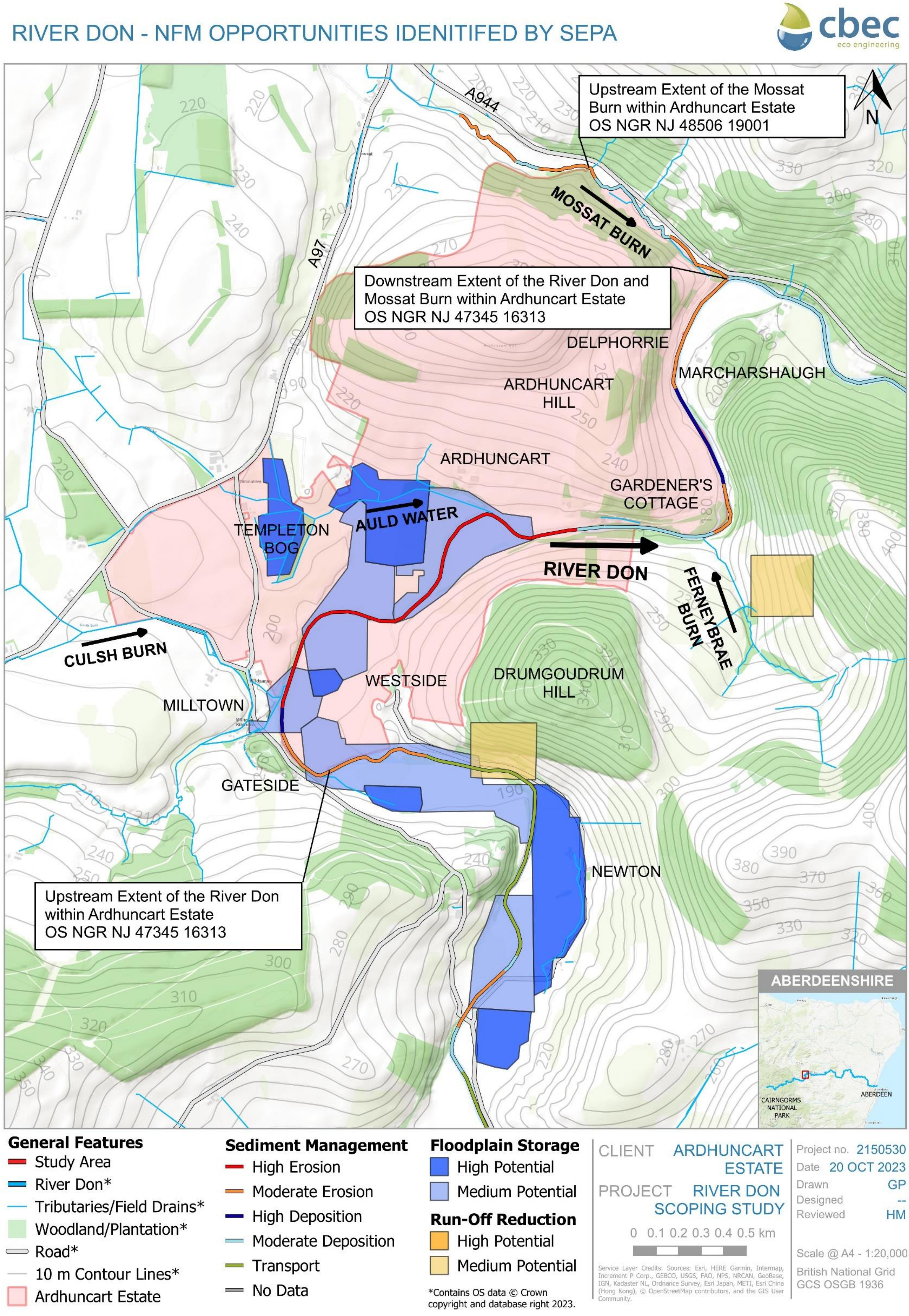

Figure 2.2 NFM opportunities identified by high-level SEPA modelling. These areas within the study site will be ground truthed as part of the geomorphic assessment.

2.6 ECOLOGY

2.6.1. Water Framework Directive Status

The Water Framework Directive (WFD) is an assessment that monitors the ecological health of waterbodies in the UK. Biological, chemical and hydrological parameters are measured to assess any improvements or deterioration in these factors within a specific waterbody. The cumulative result of this assessment is a classification of ecological quality, ranging from Bad, Poor, Moderate, Good to High. This assessment is supported by identification of targets and objectives to prevent deterioration and encourage improvement within the waterbody. These targets are used as a planning tool to protect and/or restore a river, with the ultimate aim of Good ecological status. Given the use of this tool as an assessment of ecological health and degree of deterioration, improving a waterbody's WFD status is often a key driver for river restoration funding. For assessment purposes, the WFD divided rivers into multiple sub-sections, each assigned a separate waterbody identification number. Ardhuncart Estate falls within the 'Strathdon to Alford' section of the River Don (ID: 23294), which has maintained a Good overall ecological status since the earliest available record for this section, in 2007.[10] This waterbody was last assessed in 2020. Additionally, the site is not designated as a Heavily Modified Water Body. Whilst there are no specific targets provided, owing to the waterbody already presenting Good ecological quality, the options identified within this report will seek to further improve ecology and morphology.

2.6.2. Designations

Consultation of NatureScot's online SiteLink service was undertaken to identify any ecologically designated areas within the Estate, in order to determine appropriate planning and permitting considerations. This section of the River Don is not covered by ecological designations, such as a Special Site of Scientific Importance (SSSI), according to NatureScot's database.[11] Restoration works at the site will, therefore, not be subject to protected area permissions. However, an ecological survey may be required prior to construction of any specific options to mitigate against any disturbance to existing organisms or habitats and to facilitate planning permission.

2.6.3. Riparian Corridor

The riparian zone refers to a corridor of land that encompasses a watercourse itself and a strip adjacent floodplain on both banks. These corridors are recommended to extend up to two channel widths into the floodplain, such that a 10 m wide channel would have a riparian zone with a width of ~50 m (inclusive of both banks). Riparian corridors are often limited by surrounding land management; therefore, a balance needs to be struck between benefits to the river ecosystem and the requirements of adjacent land-use. Riparian zone improvements can enhance the biodiversity and climate change resilience of riparian habitats and increase bank stability, as well as providing NFM and water quality benefits. High-level datasets created by organisations such as Forestry Scotland and Marine Scotland Science are a useful first step in the identification of priority areas for riparian planting. Data derived from these two datasets for the Ardhuncart Estate are present in Figure 2.3. These target areas will be visited during the geomorphic walkover to determine the suitability and appropriateness of riparian habitat enhancements in these locations.

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[10] https://www.sepa.org.uk/data-visualisation/water-classification-hub/?display=information_sheet&waterbodyid=23294

[11] NatureScot. 2023. Site Link Map [Online]. Last accessed on 11.09.23 via https://sitelink.nature.scot/map

The Scottish River Temperature Monitoring Network (SRTMN), established in 2013 by Marine Scotland Science, aims to assess temporal and spatial trends in river temperature and the effect of different management techniques on maintaining hospitable conditions for aquatic fauna.[12] The data obtained from this network of water temperature loggers have enabled this information to be extrapolated across Scotland, thus aiding the planning of riparian habitat improvements. Individual reaches of Scottish watercourses have been assigned a priority value ranging 0 to 10, with 0 indicating a low priority site for riparian planting (no water temperature reduction) and 10 high priority (large temperature reduction). [13] The highest priority locations are assigned according to the hottest water temperatures recorded, as well as considering the areas that are most sensitive to climatic change and offer good potential to be effectively cooled by riparian woodland. According to the SRTMN dataset, riparian tree planting (on both banks) should be prioritised to manage water temperature and climate sensitivity on the lower Mossat Burn.[14] This tributary ranked as high priority, scoring 9 out of 10. With a ranking of 6, the Don is classified as a moderate priority for water temperature management under Marine Scotland Science's assessment. The Auld Water has not been classified within this data set.

Scottish Forestry in partnership with the James Hutton Institute have identified target areas for woodland that can provide riparian benefits, as part of the Scottish Government's Forestry Grant Scheme (FGS). FGS is a funding option set up to encourage the creation of new woodlands and the sustainable management of existing woodlands. Priority areas identified within the riparian dataset have been prioritised to provide the following benefits: improvements to the WFD waterbody status and habitat diversity; and reducing water temperatures and flood risk.[15] Within the Ardhuncart Estate, this dataset indicates that the Mossat Burn and the majority of the River Don should be prioritised for riparian improvements. This correlates with current aerial imagery, showing that riparian tree cover is sparse upstream of Ardhuncart Lodge and downstream of the Gardener's Cottage along the River Don. The absence of riparian corridors along the Mossat Burn and Auld Water is also clearly visible from this satellite mapping (although, as noted above, the latter is not indicated on the FGS target areas dataset).

Identification of suitable areas for riparian planting within this report will take into consideration potential benefits to the climate change resilience of habitats, as well as potential improvements in water temperature, water quality and NFM. Additionally, the potential to intercept hydrological flow pathways to slow the rate at which surface run-off reaches the River Don during flood events will also be considered. The benefits of riparian corridor improvements are further discussed in Section 4.1.9, with implementation locations for the Ardhuncart Estate outlined in Section 4.2.

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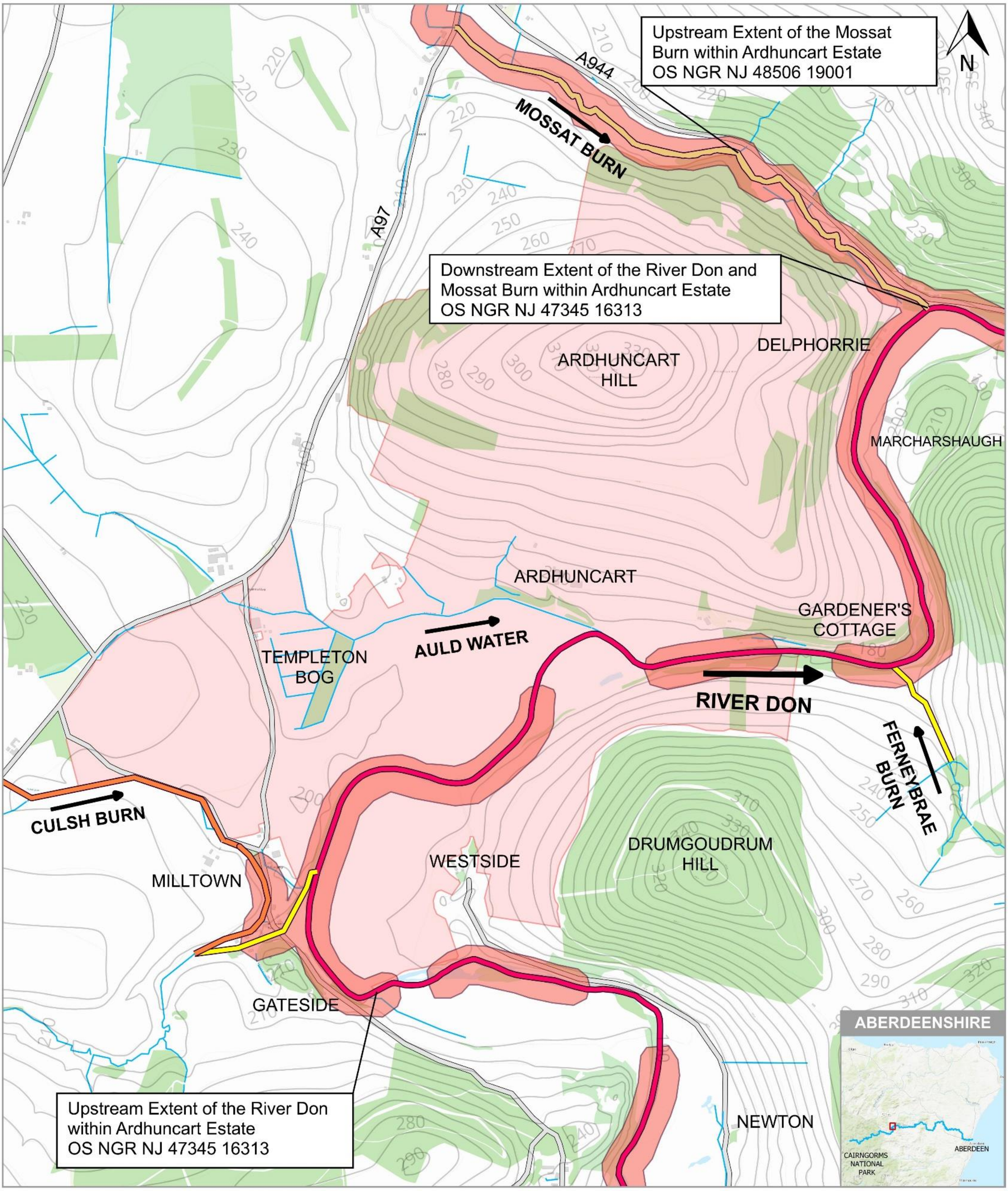
[12] Scottish Government. 2021. Scotland Temperature Monitoring Network. [Online] https://www.gov.scot/publications/scotland-river-temperature-monitoring-network-srtmn/#:~:text=The%20Scotland%20River%20Temperature%20Monitoring%20Network%20(SRTMN)&text=It%20began%20as%20a%20strategically,short%2Dterm%20deployments%20(ca.

[13] Marine Scotland Science. 2021. SRTMN - Tree planting prioritisation for shading rivers - where both banks can be planted [Online]. Last accessed on 21.11.2023 via https://marine.gov.scot/maps/1907

[14] Marine Scotland Science. 2021. Maps NMPI. Scottish River Temperature Monitoring Network: Tree planting prioritisation for river shading (planting on both banks) [Online]. Last Accessed 21.11.23 via https://marinescotland.atkinsgeospatial.com/nmpi/default.aspx?layers=1907

[15] Scottish Government. 2023. FGS Target Area – Woodlands for Riparian Benefits [Online]. Last accessed 24.11.2023 via https://www.data.gov.uk/dataset/55aa9441-f911-48b2-9b87-a2cc18a555b7/fgs-target-area-woodlands-for-riparian-benefits

RIVER DON - RIPARIAN CORRIDOR IMPROVEMENTS



Riparian Corridor Improvements

- FGS Riparian Target Areas[1]

Water Temperature Priority Score:[2]

- 6
- 8
- 9
- 10

Other Features

- Tributaries/Field Drains[3]
- Woodland/Plantation[3]
- Road[3]
- 10 m Contour Lines[3]
- Ardhuncart Estate Title Area

CLIENT ARDHUNCART ESTATE

PROJECT RIVER DON SCOPING STUDY

0 100 200 300 400 500 m

Project no.	2150530
Date	20 OCT 2023
Drawn	GP
Designed	--
Reviewed	LM

Scale @ A4 - 1:16,000

British National Grid
GCS OSGB 1936

Service Layer Credits: Sources: Esri, HERE Garmin, Intermap, Increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), © OpenStreetMap contributors, and the GIS User Community.

[1]Forestry Grant Scheme Target Area -Woodland for Riparian Benefit. Contains public sector information licensed under the Open Government Licence v3.0.
[2]Marine Scotland Science. Scottish River Temperature Monitoring Network. Tree planting prioritisation for river shading (planting on both banks). Based on digital spatial data licensed from the Centre for Ecology & Hydrology, © NERC (CEH).
[3]Contains OS data © Crown copyright and database right 2023.

Figure 2.3 Riparian corridor improvement opportunities identified by Scottish Forestry and Marine Scotland Science

2.6.4. Mossat Burn Habitat Restoration Report

A habitat restoration assessment of the Mossat Burn was undertaken by the Don District Salmon Fisheries Board (Don DSFB) in 2023.[16] The Don DSFB report indicates that the decline of both juvenile and adult Atlantic Salmon populations within the Mossat Burn is linked to a reduction in availability of suitable habitat within the burn, as well as alterations to the catchment hydrological regime due to changing land use practices and a decline in the numbers of adult salmon returning each year. Under the Conservation of Salmon (Scotland) regulation 2016, the Mossat Burn is classified as a Category 3 River, defining its Atlantic Salmon stocks as unsustainable.

The report identifies increased drainage associated with wind farms, increased run-off due to block harvesting of plantations and reduced drought resistance as potential influencing factors. Climate change is also considered to have an impact. The report focuses on the lower course of the Mossat Burn between Mossat Bridge over the A97 and the River Don confluence.

The report identified the following specific impacts on habitat condition within the Mossat Burn:

- Active erosion and deposition of substrate;
- Land drainage;
- Lack of complex riparian vegetation (including native broadleaf trees);
- Absence of instream cover for juvenile and adult salmon and trout;
- Increased frequency and intensity of high flows, likely due to climate change, increasing the risk of redd washout, reducing potential in-channel cover and creating substrate uniformity.

Installation of large wood structures (LWS) and willow bank protection, creation of floodplain wader scrapes and native tree planting were the main opportunities identified for this section of the Mossat Burn. Riparian planting was recommended to be undertaken in blocks given the overhead power cables posing a constraint and the associated potential maintenance requirements for planting within this area. LWS were proposed to provide in-channel cover as well as encouraging sediment sorting within the channel bed for spawning and creating thermal refugia for fish. These structures are effective at enhancing geomorphic processes, which promote in-channel morphological diversity and in turn encourage these habitat improvements. The benefits of this measure are further discussed within the options section of this report (Section 4.1.6).

During the geomorphic walkover, these opportunities for habitat improvement will be considered alongside measures for restoration of natural geomorphic processes within the burn. In many cases process-based restoration and habitat improvement go hand in hand; therefore, the options developed within this report will seek to deliver this dual benefit, as well as offering flood management benefits where possible.

[16] Kerr. J and Don District Salmon Fisheries Board. 2023. Mossat Burn Habitat Restoration Proposals 2023. [PDF].

2.7 HERITAGE AND ARCHAEOLOGY

A review of Historic Environment Scotland's (HES) online database was carried out to identify any site of archaeological or heritage value within the Estate. Focus was given to sites situated within the active floodplain, where the direct and indirect impacts of river restoration opportunities identified may impact the preservation or structural integrity of these protected sites.

Heritage assets located within a 1 km radius of the watercourses that fall within the Ardhuncart Estate have been listed in Table 2.1 and presented in Figure 2.4. Cross-reference between the SEPA flood mapping (Section 2.5.1) and the HES data base identified that no archaeologically designated sites are located within the functional floodplain or high flood risk areas associated with the River Don, Auld Water or Mossat Burn. Therefore, the heritage assets listed in Table 2.1 are not expected to be directly impacted by any river restoration options identified for the three watercourses. However, indirect impacts of any proposed works should be considered during the design development, should any of the proposed options be carried forward to the detailed design phase. Additionally, funding applications and planning permissions usually require any designated sites within the area of proposed works to be identified.

Table 2.1 Archaeological and heritage assets present within 1 km radius of the watercourses within the Ardhuncart Estate (Source: Historic Environment Scotland).

Name	Designation	ID Number	Location		
			Description	Grid Reference	Distance from Watercourse
Mill of Kildrummy	Category B Listed Building	LB9101	Positioned on the western side of the A97, within Milltown. This building is located outside of the River Don floodplain.	NJ 46990 16521	125 m from the River Don
Kildrummy Parish Church	Category A Listed Building	LB9093	Positioned between Kildrummy and Ardhuncart. These listed buildings and scheduled monument are located outside of the River Don floodplain, on the river left (northern side) of the Auld Water.	NJ 47227 17579	675 m from the River Don and 130 m from the Auld water
Former Manse of Kildrummy	Listed Building Category B	LB9096		NJ 47386 17626	555 from the River Don and 120 m from the Auld water
St Bride's Chapel (Kildrummy Old Parish Church)	Scheduled Monument	SM10729		NJ 47241 17556	640 from the River Don and 110 m from the Auld water
Mossat Toll House	Listed Building Category B	LB2740	Located on the upstream side of the A97 road bridge across the Mossat Burn. This building is located outside of the Mossat Burn floodplain.	NJ 47633 19542	1km from the upstream extent of the Mossat Burn within the Ardhuncart Estate

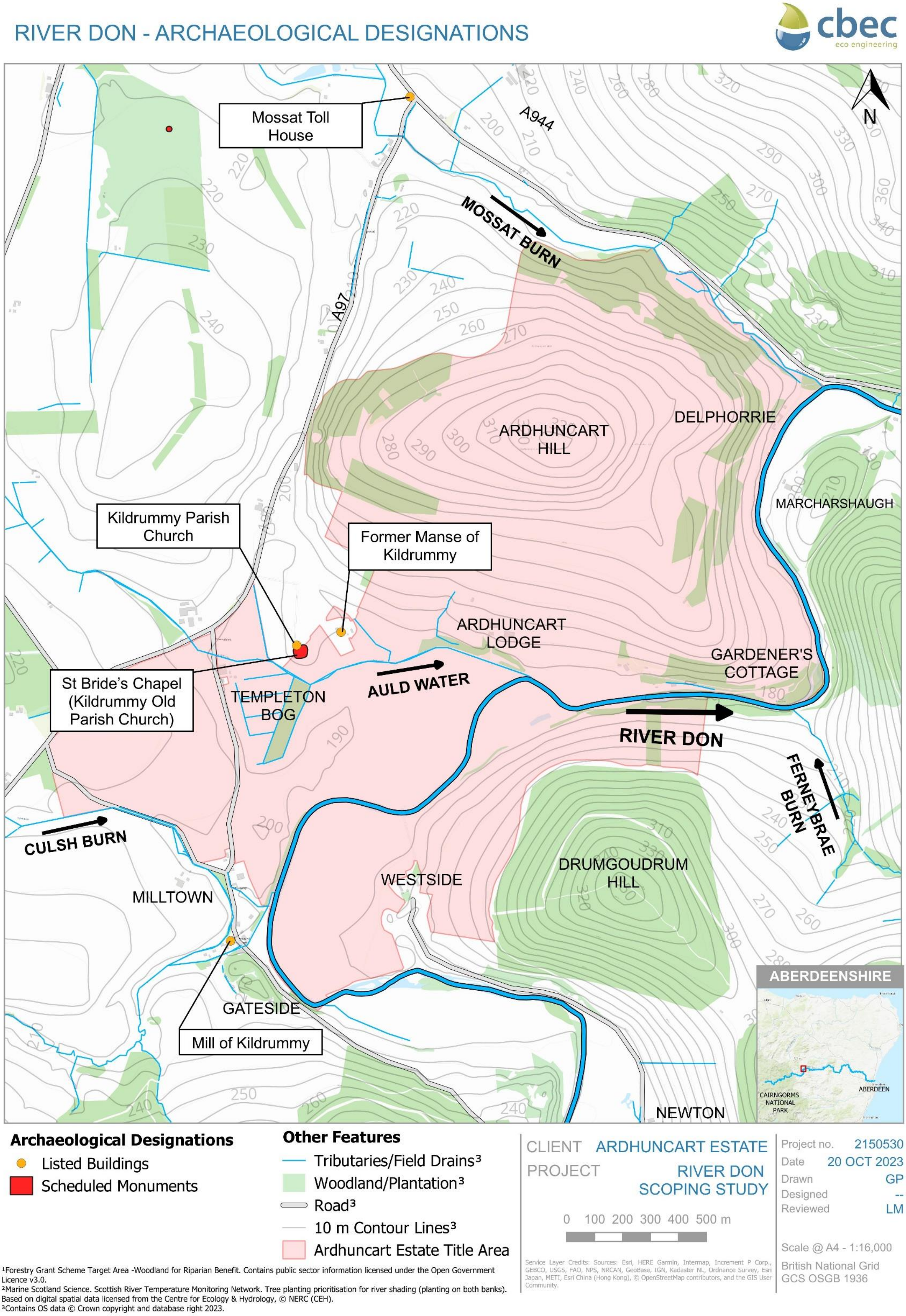


Figure 2.4 Archaeological designations recorded by Historic Environment Scotland. Heritage assets with labels have been identified as located within 1km of the River Don, Auld Water or Mossat Burn.

2.8 FUNDING

The opportunities for river restoration, habitat improvements and NFM identified within this report have been summarised in Section 4.1, alongside an outline of the next steps required to implement these measures. It is understood that the client may apply for funding to facilitate the next phases of work for the preferred options. There are several funding avenues to support the implementation of nature-based solutions for river management, for example NatureScot's Nature Restoration Fund (NRF). Key information for applicants from NatureScot has been summarised in the sub-section below, for context. A fact sheet for each restoration opportunity identified for the Estate has been provided in Section 4.1, each including a list of NRF key delivery priorities that are likely to be contributed towards by the proposed works.

2.8.1. NatureScot's Nature Restoration Fund

NatureScot's NRF offers grants for projects that seek to protect and restore biodiversity across Scotland, through terrestrial, freshwater and marine focused projects. The funding is centred around five key themes: habitat and species restoration, freshwater restoration, coastal and marine restoration initiatives, control of invasive non-native species (INNS) and enhancing and connecting nature within and between urban areas.[17]

The are three types of grant that can be applied for:

- Helping Nature (grants of £25,000 to £250,000);
- Transforming Nature - Delivery Phase (grants above £250,000);
- Transforming Nature - Development Phase (funding to support preparatory activity for large scale delivery projects of over £250,000).

Terms and conditions state that an NRF grant can only part-fund a project, such that 'a minimum of 10% of total project costs must be offered as match funding from sources other than NRF'.[18] For example, a scoping study funded by the Estate, such as this report, could count towards this 10% contribution to the project.

Restoration opportunities described within this report are expected to fall within the Helping Nature cost bracket for design and build. Options identified will focus on freshwater restoration as well as those measures that will benefit habitat and species. This report has been set out to aid the client in completing an Expression of Interest (EOI) form, which is the first step in applying for this funding. If the EOI is successful, then a full application for an NRF grant can be submitted. Table 2.2 sets out the upcoming grant application deadlines.

[17] NatureScot. 2023. Nature Restoration Fund – Priorities for Action [Online]. Last accessed 11.09.23 via https://www.nature.scot/doc/nature-restoration-fund-priorities-action

[18] NatureScot. 2023. Nature Restoration Fund – Expression of Interest form [.doc]. Available at: https://www.nature.scot/doc/nature-restoration-fund-2023-expression-interest-form

Table 2.2 NatureScot's Nature Restoration Fund application rounds and deadlines.

Application Deadline	Anticipated application Decision
Monday 29 January 2024 at 12 noon	late April/early May
Thursday 25 April 2024 at 12 noon	July
Monday 12 August 2024 at 12 noon	November

River restoration construction works should be undertaken outside of the Salmonid spawning season (i.e. September to February) to minimise disturbance to these organisms where possible. Therefore, if the client wishes to go to construction in 2024, an application in January 2024 would be required.

3. GEOMOPRHOLOGICAL WALKOVER

cbec undertook a geomorphological walkover of Ardhuncart Estate on 12th and 13th September 2023. Weather conditions were generally dry and river levels were at the lower end of the normal range for the River Don, recorded as 0.625 m at the Alford gauge, which is situated ~10 km downstream of the study site. The survey covered the full extent of the mainstem River Don within the Estate boundary and included a reconnaissance-level survey of main tributaries (including the Auld Water and Mossat Burn) and relevant floodplain features. This allowed the assessment of current morphological features, processes and pressures on the river system and allowed identification of any constraints or pressures that may influence the development of restoration options. The target areas were assessed to determine the applicability of potential restoration and management options. In particular, the following key factors were considered:

- geomorphic characteristics of the watercourse (focusing on reach type and bed substrate, as key indicators of channel slope, sediment dynamics and thus potential for geomorphic work);
- morphological pressures impacting the natural form and function of the watercourse;
- site setting, including current land use, topography and geomorphic characteristics (i.e. channel/floodplain connectivity);
- constraints that may potentially limit restoration works (i.e. a high-level assessment to be supplemented at outline/detailed design stage for any opportunities to be taken forward).

Observations for each of the main target areas are summarised below. Based on information gathered during the geomorphic assessment and desk-based assessment, supplemented with liaison between the client and cbec's project team, a longlist of suitable measures has been developed. Further information on the longlisted options and the options appraisal process is presented in Section 4.1.

3.1 RIVER DON

The River Don between Strathdon and Alford is designated as being in ecologically good condition under the Water Framework Directive (Section 2.6.1). As noted in the previous section, river basin management plans and restoration works are often applied to degraded watercourses to seek to achieve 'Good' WFD status, which is seen as an acceptable standard across the UK. However, this study provides an opportunity to carry out works that will ensure that this Good ecological status is maintained and, through a cumulative approach in which multiple opportunities are implemented, contribute towards the restoration of High ecological condition.

In line with this WFD status, the River Don was observed to exhibit good morphological diversity, typically exhibiting a pool-riffle morphology with occasional alluvial barforms (depositional zones within the channel bed), characteristic of rivers exhibiting a meandering planform. A plane-bed reach was also noted between Macharshaugh farm buildings and the Mossat Burn confluence. The latter reach type is associated with coarser bed material (boulders and cobbles), which has the potential to provide good parr habitat. Broadly, a diverse range of morphological features was observed throughout the Estate, although the heterogeneity of morphological units is likely to be lower than may be expected under 'natural' conditions. Additionally, alluvial bar features were noted to be limited in both size and extent across the Estate. This presents an opportunity to enhance alluvial depositional processes through the introduction of large wood structures (LWS), thus increasing the diversity of the riverbed morphology and in turn enhancing habitat provision (Section 4.1.6).

Embankments and stone walls were observed to be running parallel to the channel, both along the top of bank and set back within the riparian corridor of the River Don, limiting channel-floodplain connectivity. Within the upstream half of the Estate, where the valley topography allows for a wider floodplain, the embankment and stone walls are limiting flood storage potential and may also be preventing the return of flood or surface water back to the channel. A handful of localised sections of bank protection were noted across the site, typically associated with bridges. However, this bank protection was deemed to be a minor constraint to the geomorphic function of the River Don; therefore, removal of this protection has not been prioritised within the options identified (Sections 4.1 and 4.2). Sections of bank erosion were noted on the river left bank on the approach to Cleek-Him-In-Pot pool and at Jock Reid Pool (Figure 3.7), the latter associated with the embankment breach area located between this pool and the bridge across to Westside. Bank reprofiling and protection works are recommended to mitigate against further erosion within these areas (Section 4.1.8).

A series of restoration opportunities have been identified that offer the potential to deliver in-channel, bank and flood improvements to both the geomorphic and ecological health of the River Don. Some of these measures also offer potential natural flood management benefits, although detailed modelling would be required to quantify these benefits. These opportunities are outlined in in Section 4.1, with specific locations for implementation presented 4.2.

Figure 3.1. On approach to Cleek-Him-In-Pot pool, showing alluvial bar form on the river right bank and bank erosion on the river left.

Figure 3.2 Looking upstream to the upstream extent of the River Don within Ardhuncart Estate, showing the meandering planform with alluvial bar form. Bar forms are generally poorly developed throughout the remainder of the site.

Figure 3.3. Proto-bar form present on the river right bank, between Cleek-Him-In-Pot and Jock Reid pools. This feature could be enhanced by installing a LWS to promote in-channel morphological and habitat diversity.

Figure 3.4. Example of the stone wall along the top of the River Don right bank, limiting channel floodplain connectivity.

Figure 3.5. Stone toe protection present intermittently throughout. Photo shows a section of river left bank protection downstream of Cleek-Him-In-Pot pool.

Figure 3.6. limited riparian corridor on river left and right banks between Cleek-Him-In-Pot and Jock Reid pool. Overhead cables on the river left may be a constraint to riparian planting.

Embankment breach area between Jock Reid Pool and the Westside Bridge

Figure 3.7. Bank erosion on the river left bank at Jock Reid pool, just upstream of the embankment breach area.

Figure 3.8 Looking across the channel to the embankment breach area on the river left bank.

Figure 3.9. Looking upstream at the bank erosion, showing the low section of channel bank (~1 m high) at the embankment breach area.

Figure 3.10. Looking downstream along the embankment breached bank, showing the cobble/gravel bar form that has developed along this side of the channel.

Figure 3.11. Cobble, gravel and fine sediment deposited on the floodplain within the embankment breach area.

Figure 3.12. Embankment breach area. Continuous tree line on the top left of this photo shows the position of the Auld Water.

Figure 3.13. Westside bridge, which was historically positioned further downstream (Section 2.4).

Figure 3.14 Section of lower lying floodplain, on the river left bank downstream of the Westside bridge, used for arable farming.

Figure 3.15. Looking downstream towards the Auld Water confluence, entering the channel from the river left bank.

Figure 3.16. Looking downstream towards the Gardener's Cottage garages.

Figure 3.17. Drainage ditch between the road to Ardhuncart Lodge and the Gardener's Cottage garage.

Figure 3.18. Anecdotal evidence identified that flood water returns to the channel at this point on the river left bank, outside of the Gardener's Cottage.

Figure 3.19. Looking upstream from the bridge between Delphorrie and Macharshaugh.

Figure 3.20 Bridge between Delphorrie and Macharshaugh.

Figure 3.21. Looking downstream towards Delphorrie from the bridge.

3.2 AULD WATER

The Auld Water is assumed to have been straightened and realigned prior to the 1850s to facilitate agricultural land gain. This tributary presents an over-deepened channel geometry with limited morphological diversity, presumed to be because of these realignment works, disconnecting it from the floodplain. SEPA NFM opportunity modelling, reviewed during the desk study, identified this area as offering medium to high floodplain storage potential (Section 2.5.3). Therefore, river management options identified for this watercourse should seek to improve floodplain connectivity through realignment and water retention within wetland scrapes and/or wet woodland areas. Opportunities for the Auld Water are summarised in Sections 4.1 and 4.2.

A field access bridge crosses the Auld Water upstream of the Ardhuncart Farm buildings. This structure has a low soffit level that, combined with an accumulation of fine sediment on the channel bed, has caused a backwater effect upstream and restricted flow conveyance downstream. Sediment management and bridge alterations are recommended to improve the longitudinal connectivity of this watercourse for flow and sediment transfer (Section 4.1.11).

At the Auld Water/Don confluence, increased nutrient levels were noted through the presence of algae on the riverbed substrate, which was not observed further upstream on the Don. The bed of the Auld Water itself was also vegetated with macrophytes and grass, further indicating a high nutrient supply. This may be because of agricultural or road run-off; however, a specific point-source was not observed during the walkover. Riparian corridor improvements along the Auld Water and mainstem Don may help to slow the movement of surface water and encourage nutrient settlement (Section 4.1.9).

Templeton Bog, which drains into the Auld Water, was also visited during the geomorphic walkover to assess potential for restoration and NFM. On the south-eastern edge of the bog, young broadleaf trees and evidence of recent tree planting (i.e. within the last five years) were noted. This planting could be extended across this area, in combination with ditch blocking (Section 4.1.7) and creation of floodplain scrapes (Section 4.1.3), in order to promote the development of both a wet woodland habitat (Section 4.1.5) and a flood storage area. Existing woodland on the river left bank of the Auld Water for ~450 m upstream of the Don confluence also offers potential for wet woodland development/enhancement, following improvements to channel-floodplain connectivity.


Figure 3.22. Looking upstream towards Templeton Bog. The channel becomes more incised upstream of this point, compared to the section downstream that runs through the River Don floodplain.


Figure 3.23 Collapsing fence line on the river right bank, indicating bank instability. It is recommended that this fence line is set back, the bank reprofiled and riparian zone planted.


Figure 3.24. Auld Water, looking upstream towards St. Bride's Chapel. Channel overgrown with macrophytes, indicating high nutrient and fine sediment input.


Figure 3.25. Looking upstream from the track, along the Auld Water. Broadleaf woodland and scrub vegetation are present on the river left floodplain, which presents potential for wet woodland habitat.


Figure 3.26. Track over the Auld Water, ~10 m upstream from the Don confluence. The channel passes through a culvert at this point.


Figure 3.27. Looking in an easterly direction across Templeton Bog, showing the section of existing woodland on the south-eastern side of this area.

3.3 MOSSAT BURN

The Mossat Burn downstream of the A97 road bridge exhibits a plane-bed reach type, characterised by a cobble/gravel bed substrate and with the morphological units dominated by runs. Analysis of historical mapping indicated that the planform of this meandering watercourse has remained largely the same over the last ~200 years, with only minor adjustment in the meander bends noted. Observations made during the geomorphic walkover confirmed that the burn exhibits signs of natural recovery following its historical modifications to power the local milling industry.

The historic assessment (Section 2.4) identified two side channels, two sluice gates and one weir were present along this section of the Mossat Burn, remnant of the milling industry in this area. During the geomorphic walkover, the sluices were found to no longer be present and a boulder weir, noted to be partially intact. Remnants of the side channels were still present, however some sections were indistinguishable from the floodplain where sediment accumulated over time had infilled the channel and/or become overgrown by vegetation. The inlet to the lower side channel, adjacent to the weir, had been blocked by boulders. These channels could be reconnected to the Mossat Burn to increase in-channel habitat provision and increase the complexity of this lower reach, with the potential to slow the movement of water through this area to the Don.

Occasional alluvial bar forms (i.e. areas of sediment deposition on the channel bed) were noted throughout the site. The size, abundance and complexity of these morphological features could be enhanced through the introduction of LWS and porous log jams (PLJs) to increase the retention of gravel within this section of the burn. Further details in relation to these opportunities are provided in Section 4.1 and Table 4.7 and Table 4.8.

The Mossat Burn between the A97 road bridge and the Mossat−Don confluence is situated within a relatively confined valley (topographically). Findings from the geomorphic walkover, informed by the topography (Section 2.2.2) and flood mapping (Section 2.5.1), indicate that any works undertaken to enhance channel-floodplain connectivity would be relatively contained within the narrow valley. Therefore, restoration works undertaken within this reach are likely to pose a low risk of flooding of the surrounding area.

Telegraph poles and associated powerlines that zigzag across the Mossat floodplain within this lower section of the burn would pose a significant constraint to restoration. Hydraulic modelling would be required to ensure that any proposed channel works would not pose a risk to this utility infrastructure. The A97 road is oriented north to south along the river left valley side throughout the lower Mossat. This transport route was deemed to be at low risk from any in-channel or floodplain works carried out within this area of the Mossat Burn, due to its elevated position on the valley side, above the functional floodplain. Additionally, the Mossat is known to provide good Salmonid spawning habitat; accordingly, options should be developed with sensitivity to these pre-existing habitats.

The geomorphic walkover identified opportunities that align with and build upon those identified by the Don DSFB for the Mossat Burn (Section 2.6.4). These opportunities have been summarised in Sections 4.1 and 4.2. The cumulative effect of these measures has the potential to slow the movement of water through the lower Mossat to the Don, providing NFM benefits as well as habitat enhancements and the restoration of more natural geomorphic function.

The burn upstream of the A97 road bridge was not surveyed as part of the walkover; however, the watercourse appears to have heavily straightened and the adjacent land drained between Birkenbower and Bridgeend, indicating that restoration within this area could provide considerable morphological benefit to this watercourse, despite being outwith the Ardhuncart Estate. Other opportunities such as this would be expected to be identified should a catchment-scale scoping study be undertaken for the River Don (see Section 4.1, Table 4.14).

Figure 3.28. Cobble/gravel bed substrate is dominant throughout the lower Mossat, with few bar forms.

Figure 3.29 The Mossat burn is typically 1.5 m wide and 1 m deep. This photo also shows the overhead telegraph wires which run across the floodplain throughout the lower Mossat.

Figure 3.30. Rushes on the floodplain indicate good channel/floodplain connectivity and high-water table. Implementation of LWS here could promote increased out-of-channel flows.

Figure 3.31. Typical plane bed morphology present throughout the site.

Figure 3.32. Partially intact boulder weir located at OS NGR NJ 48849 18692.

Figure 3.33. Looking upstream across the floodplain from the westen valley side, near the boulder weir.

Figure 3.34. Looking downstream across the floodplain from the westen valley side, near the boulder weir.

Figure 3.35 The Mossat burn upstream of the Ardhuncart Estate access track bridge. Slow glide morphology indicates that the channel is constricting flow and creating a backwater effect.

Figure 3.36. Arch bridge providing vehicular access to the Ardhuncart Estate. This bridge is positioned ~80 m upstream from the Mossat-Don confluence OS NGR NJ 49038 18555.

4. OPTIONS DEVELOPMENT

4.1 OPTIONS LONGLIST

Based on the findings of the desk-based assessment, the geomorphic walkover and initial discussions with the Ardhuncart Estate landowner and associated parties, a 'longlist' of potential options has been developed. This longlist presents restoration and management options that are considered both appropriate for the River Don catchment and likely to yield benefits for ecology, geomorphology and/or flood risk. The potential impacts on ongoing land management and maintenance and the overall 'buildability' of each option were also considered during this process.

A summary of the recommended restoration options identified and the watercourse(s) or area(s) within the Estate where they could be applied are provided in Table 4.1. Specific implementation locations have been outlined in the subsequent Section (4.2).

Table 4.1 River restoration and management measures identified within the Ardhuncart Estate.

Option		Implementation Location[19]			
		River Don	Auld Water	Mossat Burn	Templeton Bog
1	Side channel Reconnection				
2	Embankment/Wall Removal				
3	Floodplain Scrapes				
4	Channel Realignment				
5	Wet Woodland				
6	Large Wood Structure Installation				
7	Porous Log Jam Installation				
8	Bank Reprofiling & Green Bank Protection				
9	Riparian Corridor Improvements				
10	Set Back Fence Lines				
11	Bridge Alterations				
12	Weir Removal/Alterations				
13	Catchment Study				

[19] These watercourses have only been surveyed within the Ardhuncart Estate boundary. Therefore, this is not an exhaustive list of opportunities present across the full length of these watercourses. Further restoration opportunities, beyond the Estate boundary, should be explored within the catchment study (Option 13).

Each longlisted option is summarised below (Sections 4.1.1 to 0). A fact sheet has been provided for each option, outlining the anticipated benefits alongside any risks and uncertainties associated with the restoration measure. Potential mitigation measures have been suggested to reduce these risks, where appropriate, and an indication of further surveys required to progress the project to concept or detailed design phase has been provided. These fact sheets are designed to aid the shortlisting of options that the landowner may wish to progress and will provide information to support applications for funding for future stages of work.

At this stage of the options appraisal process, a subjective, qualitative assessment based on available information has been made regarding the development potential, deliverability and cost of each of the proposed options. It should be noted that, at the scoping/feasibility stage of a project, there are still a significant number of unknowns relating to the final design; therefore, these assessments should be used with caution and the associated risks understood. Each of the longlisted options has been colour coded as summarised in Table 4.1 to provide an overview of the technical feasibility of the option. It is important to note that the feasibility of delivering a given option may increase or decrease when various options are combined within a single implementation area.

Table 4.1 Qualitative classification for development deliverability and costs.

Development	Deliverability	Cost
No site-specific design or additional surveys required. Limited consenting requirements	Manual work requiring minimal unskilled labour and little or no machinery.	Low (£1k-£5k)
Outline design drawings. Some consenting and additional surveys likely.	Requirement for some machinery and skilled labour.	Medium (£5k-£25k)
Detailed design and modelling. Additional surveys and consents required.	Complex construction requiring heavy machinery, multiple personnel, and specialised staff.	High (>50k)

4.1.1. Side Channel Reconnection and Creation

Side channels are an important component of unmodified river ecosystems and provide important spawning and rearing habitat for salmonids (Figure 4.1). In natural systems, side channels are often associated with complex floodplain ecosystems, including wetlands, ponds and large wood. However, historically, simplification/channelisation of rivers has resulted in side channels being intentionally blocked and disconnected from mainstem rivers to support surrounding land use and management. This disconnection of important habitat concentrates the full flow in the mainstem river channel and exacerbates flooding downstream, as well as degrading floodplain habitat.

Reconnecting side channels can often be as simple as removing boulders that were put in place historically to block the channel, or excavating channel infill at the side channel entrance to encourage flow to be reinstated through the channel. Hydraulic reconnection of the side channel with the main channel can be supplemented by habitat improvements, including the addition of large wood to the reinstated channel or improvement to the riparian zone. At some sites, reconnecting the channel may be more complex or technically challenging, or there may be a requirement to ensure that the channel is active over a specific range of flows or to constrain the risk of avulsion. For such sites, topographic survey, modelling and design may be required to ensure that the side channel functions as desired.

A number of opportunities for side channel reconnection were identified along the River Don and Mossat Burn corridors. In particular, reconnection and naturalisation could be undertaken for the two old mill lades present on the river right (western) side of the lower Mossat, which could provide additional in-channel habitat and flow capacity within the channel network. Additionally, there is considered to be potential for creation of a new side channel where the embankment has been breached downstream of Jock Reid Pool; however, it is important to note that construction of a new side channel will require a greater level of intervention (with associated cost and complexity) than reconnecting existing historical side channels.

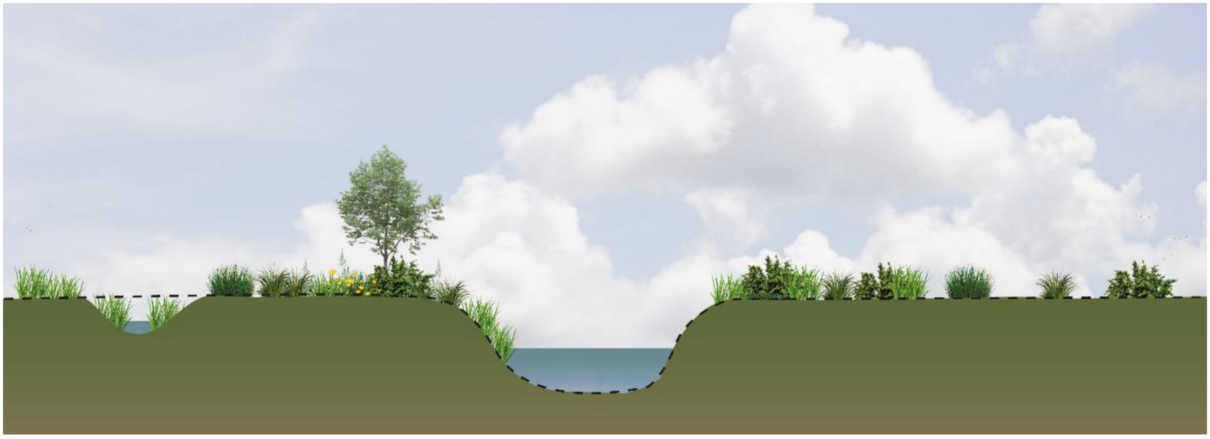


Figure 4.1 Indicative cross section illustrating side channel reconnection.

Anticipated benefits of side channel reconnection and creation, as well as any risks, uncertainties and associated mitigation measures have been summarised within Table 4.2. This table also outlines the next steps required to implement this option and details any potential maintenance requirements following completion of the construction works.

Table 4.2 Qualitative assessment of side channel reconnection

Measure	Side channel reconnection	**Location**	River Don, Mossat Burn
Development	**Deliverability**		**Cost**

Description

- Reconnection of side channels that have been blocked historically
- Can often be achieved simply by removing boulders/embankments or excavating material at side channel entrances to allow side channel flow to be reinstated
- Aims to restore fish access and improve side channel and riparian habitat
- Combine with additional riparian habitat improvements (e.g. tree planting, wetland development) for maximum benefit

Advantages/Expected Positive Effects

- Simple reconnections can be achieved relatively easily and with relatively low cost
- Provision of additional spawning and rearing habitat for fish
- Diversification of habitat and restoration of more natural river form and process, promoting self-sustaining river system
- Provision of additional habitat (e.g. for birds, invertebrates) and improvements in habitat connectivity
- Improvements in climate resilience (flood and drought) through enhanced retention of water on floodplains
- Provide cover for fish, reducing impact of increasing water temperatures
- Provide refugia for fish during flood events
- Contributes to NRF priority themes through:
  - NFM and reconnecting rivers to floodplains
  - Restoring watercourses
  - Reducing flow
  - Mitigating water temperature increases
  - Increasing ponds and water/wetland habitat
  - Making more space for streams and riparian habitat
  - Adopting nature-based approaches to managing key ecosystems
  - Favouring diversity of species and habitat structure

Disadvantages/Potential Negative Effects

- Reconnection at some sites may require additional design/modelling work (with associated cost) to ensure appropriate level of connectivity under a range of flows
- Some disruption to existing habitat during construction
- Some risk of future, unpredictable channel change (e.g. avulsion of main channel into side channel) – can be constrained and mitigated through modelling and design

Maintenance Requirements

- Limited to no long-term maintenance required
- Regular monitoring (e.g. by fixed point photography, repeat topographic survey) to ensure effective channel function (recommended, but not essential)
- Monitoring of habitat improvements (recommended, but not essential)

Next Steps

- Geomorphic walkover to survey side channels in detail and provide site-specific recommendations for design
- Tender for a suitably experienced contractor (note that works should be undertaken outside of the salmonid spawning season, i.e. outwith September to February)
- Apply for funding – both geomorphic walkover and construction phases of work may be eligible for funding

4.1.2. Embankment/Wall Removal

Embankments have typically been constructed historically to increase the natural bank height, retaining water within the channel above the natural bankfull height. In an unmodified system, out of bank flow onto the floodplain would be expected at water levels above the natural bankfull height. When water spreads across the floodplain, it dissipates the energy within flows, thus reducing erosive force. In contrast, where embankments are present, flow (and, therefore, energy) is confined within the channel over a greater range of flood flows/water levels, thus increasing the amount of energy transferred downstream and exacerbating flood impacts downstream, relative to natural conditions.

Throughout the Ardhuncart Estate, the River Don is bounded by a low field boundary wall that is approximately 0.5 m in height and was observed intermittently within the riparian corridor. In some sections, this wall forms part of an embankment, with embankment material at the base and the wall resting on top. In some places, the wall/embankment is set back from the top of bank, providing a buffer zone for channel adjustment between the River Don and the surrounding agricultural land. However, in other areas, the wall/embankment is situated at the top of bank, limiting channel-floodplain connectivity at high flows. It is understood that these linear features will be necessary in some areas to protect farmland; however, removal of or setting back the wall/embankment from the top of the bank would create space for improved geomorphic process and habitat enhancements and could be undertaken in conjunction with opportunities such as side channel reconnection and riparian zone improvements.

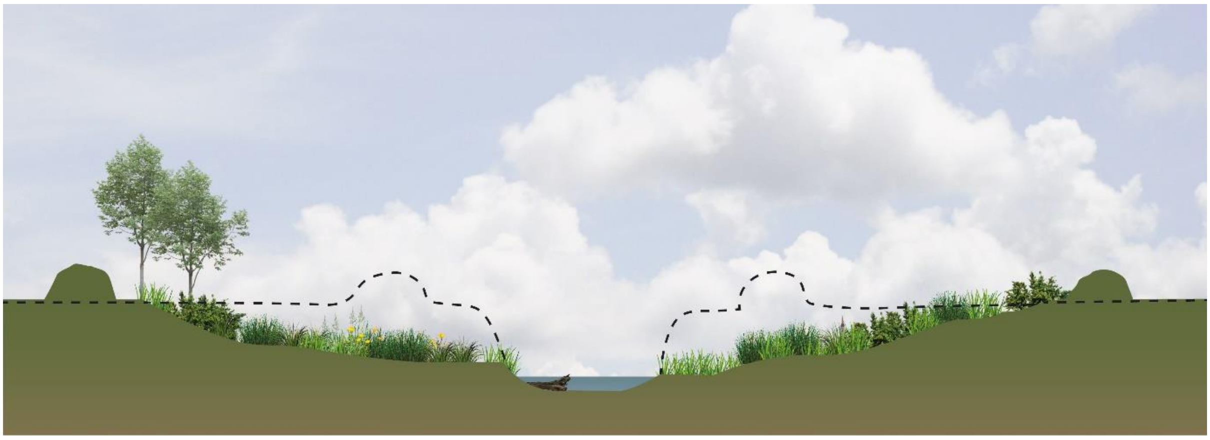


Figure 4.2 Indicative cross section illustrating embankment or wall removal.

Table 4.3 Qualitative assessment of embankment/wall removal

Measure	Embankment/wall removal	Location	River Don
Development	Deliverability	Cost	

Description

- Removal, breaching, lowering or setting back of embankments/walls, where constraints allow
- Can incorporate reprofiling of banks to achieve more natural cross section
- Can be undertaken alongside other opportunities, including side channel reconnection and riparian zone improvements

Advantages/Expected Positive Effects

- Increased connectivity between channel and floodplain
- Creation of more space for natural adjustment of river channel
- Benefits for riparian ecosystem, directly through associated habitat improvements and indirectly through move towards more self-sustaining channel/floodplain system
- Increased resilience to climate change (flood and drought) through enhanced retention of water on floodplains
- Reduction in fine sediment load of river and improved soil health owing to increased deposition on floodplains
- Reduced erosion risk at site and downstream
- Reduced flood risk downstream
- Reduced risk of unpredictable failure/breach of embankments during flood events
- Contributes to NRF priority themes through:
  - NFM and reconnecting rivers to floodplains
  - Restoring watercourses
  - Reducing flow
  - Increasing ponds and water/wetland habitat
  - Making more space for streams and riparian habitat
  - Adopting nature-based approaches to managing key ecosystems

Disadvantages/Potential Negative Effects

- Increase in flooding locally
- Requirement for land take/land repurposing to support measures
- Some disruption to existing habitat during construction
- Design and construction may be costly depending on site-specific factors

Maintenance Requirements

- Some long-term maintenance may be required depending on preferred option but maintenance load likely to be reduced
- Regular monitoring (e.g. by fixed point photography, repeat topographic survey) to ensure effective channel/floodplain function (recommended, but not essential)
- Monitoring of habitat improvements (recommended, but not essential)

Next Steps

- Geomorphic/design walkover and topographic survey to assess embankments in detail
- Detailed design and hydraulic modelling/flood risk assessment may be required
- Geotechnical investigation of embankment composition may be required
- Tender for a suitably experienced contractor (note that works should be undertaken outside of the salmonid spawning season, i.e. outwith September to February)
- Apply for funding – both design and construction phases of work may be eligible for funding

4.1.3. Floodplain Scrapes

Scrapes are shallow ponds that form naturally in areas of lower floodplain topography, often in association with relict meanders that have become partially infilled over time (Figure 4.3). These wetter areas provide important habitat for wildlife, especially in agricultural areas where the existing habitat has been simplified and degraded over time. In particular, these features provide important habitat for aquatic wildlife, wading birds, amphibians and small mammals and are often the only wet habitat in farmed landscapes, which can make them important as wildlife corridors. Scrapes can be designed specifically to meet habitat requirements of target species if required and can be fed by rivers, surface water, rainfall and/or groundwater and are often dry during the summer months but can store water in the winter months. Scrapes can contribute to flood management, although the flood risk benefit from constructing/enhancing scrapes in a single area is likely to be modest.

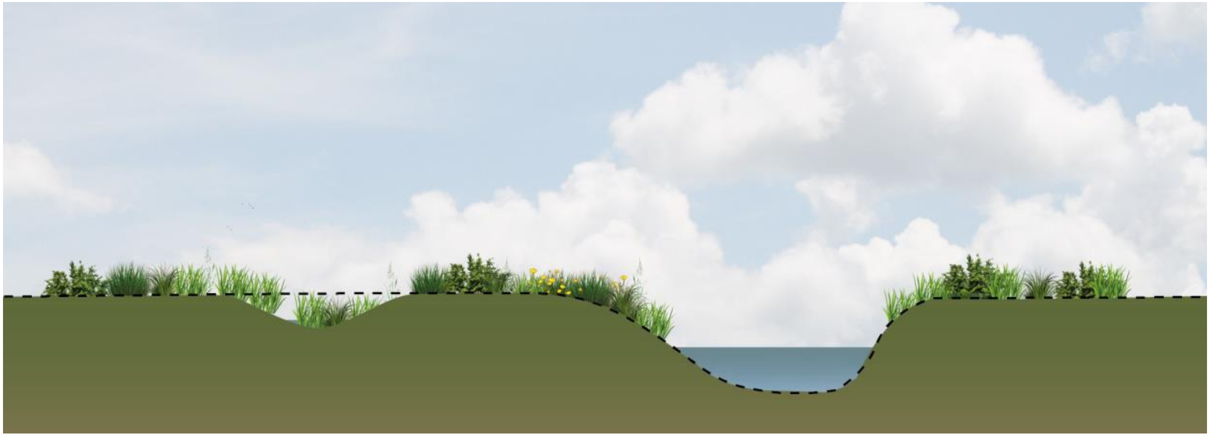


Figure 4.3 Indicative cross section illustrating floodplain scrapes.

Existing topographic lows can be enhanced to create larger scrapes and new scrapes can be constructed in association with other measures such as channel realignment (Section 4.1.4) and installation of porous log jams (Section 4.1.7), which seek to increase the channel-floodplain connectivity. Designed scrapes are typically less than 1 m deep as most submerged plants cannot grow in deeper water. Scrape design can be relatively simple, although it is generally recommended that larger scrapes be designed as a 'pond complex' with an undulating profile and a mix of deeper and shallower areas to increase the biodiversity. In all cases, scrapes should have gently sloping marginal areas. Scrapes can be combined with other habitat improvements (e.g. planting of floodplain or riparian woodland) to maximise benefits and increase the diversity of relatively uniform areas.

Excavation of floodplain scrapes is recommended within Templeton Bog to increase the inundation and residence time of water within this area (Figure 4.4), ultimately slowing the movement of through the Auld Water catchment areas and into the River Don. This work could be combined with porous log jam installation within the drainage ditches that dissect the bog and riparian planting to create a wet woodland environment. Scrapes were also recommended by the Don DSFB, for habitat improvements within the lower Mossat Burn. Similarly to the Templeton Bog, floodplain scrapes could be created in combination with sections of the Mossat Burn where log jams are proposed to be installed, to benefit from the increased channel-floodplain connectivity driven by these structures. Additionally, scrapes could provide further benefit within the floodplain adjacent to the embankment breach area, potentially helping to slow the movement of water downstream to the lower half of the Estate during flood events (Figure 4.5).

Figure 4.4 Looking towards the north-east across Templeton Bog towards St. Bride's Chapel. Floodplain scrapes could be excavated to enhance flood storage within Templeton Bog.

Figure 4.5 Looking towards the west across the River Don towards the floodplain between the embankment breach area and the Auld Water. Areas of the floodplain could be excavated to create wetland scrapes and ponds to enhance existing areas of surface water residence.

Table 4.4 Qualitative assessment of floodplain scrapes

Measure	Floodplain scrapes	**Location**	River Don, Mossat Burn, Auld Water, Templeton Bog
Development	**Deliverability**		**Cost**

Description

- Enhancement of existing topographic lows or excavation of shallow scrapes/ponds
- Scrapes typically up to 1 m deep with mix of deeper and shallower areas and gently sloping margins
- Larger pond complexes should have mix of deeper ponds and shallower/exposed central island features
- Can be combined with other habitat improvement opportunities such as riparian or floodplain woodland

Advantages/Expected Positive Effects

- Considerable benefits for ecology and habitat connectivity (e.g. by creating wildlife corridors)
- Increased biodiversity of uniform areas, e.g. by encouraging development of diverse 'mosaic' of habitat types, particularly if undertaken in conjunction with other opportunities
- Modest flood storage benefit and can utilise areas already at risk of flooding
- Can be designed to encourage colonisation by target species if desired
- Increased resilience to climate change (flood and drought) through enhanced retention of water on floodplains
- Design and construction typically relatively simple and low cost
- Contributes to NRF priority themes through:
  - Making more space for various habitat types, including ponds
  - Supporting changes in management to favour species diversity
  - Adopting nature-based approaches to managing key ecosystems
  - NFM and reconnecting rivers to floodplains
  - Increasing ponds and water/wetland habitat

Disadvantages/Potential Negative Effects

- Potential increase in flooding locally
- Some land take/land repurposing may be required
- Some disruption to existing habitat during construction

Maintenance Requirements

- Some long-term maintenance may be required (e.g. ponds/scrapes may fill in over time if inundated regularly by river sediment)
- Regular monitoring (e.g. by fixed point photography, repeat topographic survey) to ensure effective function (recommended, but not essential)
- Monitoring of habitat improvements (recommended, but not essential)

Next Steps

- Additional topographic analysis and site walkover to locate specific areas suitable
- Consideration of regulatory requirements, particularly regarding excavation within floodplains
- Tender for a suitably experienced contractor
- Apply for funding – both design and construction phases of work may be eligible for funding

4.1.4. Channel Realignment

Rivers and streams of all sizes have a tendency to adjust laterally but have historically been straightened to facilitate land gain and deepened to increase flood conveyance, typically to support agriculture, industry or urban development. In particular, straightened and over-deepened drainage ditches, which have been simplified considerably relative to natural conditions, are a common feature of agricultural landscapes; these degraded systems often have little potential for self-recovery, meaning that a greater degree of intervention is required to restore natural river processes. Re-meandering a channel (Figure 4.6), or otherwise altering its cross section or planform, is therefore often the most feasible option for restoration of a dynamic, self-sustaining river system. Channel realignment can be costly and complex owing to the requirement for detailed design and modelling and the large-scale nature of the measures, although these disadvantages are generally outweighed by the multiple benefits that such restoration can bring. In settings where large-scale realignment is not possible, such as where the available floodplain space for restoration works is more limited, the form of the channel can be altered to create a two-stage channel within a defined river corridor; this typically involves a more sinuous low-flow channel with areas of inset floodplain (Figure 4.7). There is considered to be good potential for realignment of the Auld Water or construction of a two-stage channel, ideally in conjunction with wider-scale restoration of the surrounding floodplain.

Figure 4.6 Indicative cross section illustrating channel realignment.

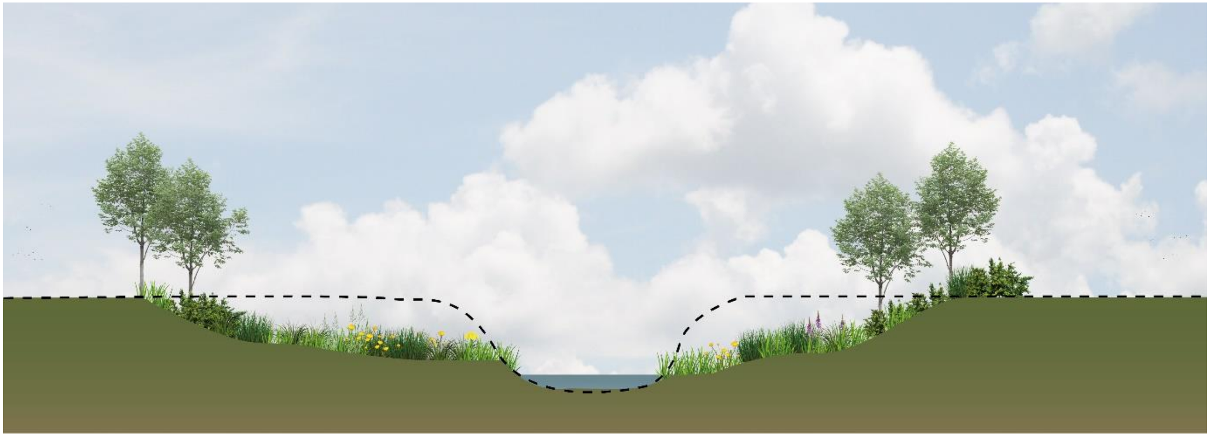


Figure 4.7 Indicative cross section illustrating construction of two-stage floodplain.

Table 4.5 Qualitative assessment of channel realignment

Measure	Channel realignment	**Location**	Auld Water
Development	**Deliverability**		**Cost**

Description

- Design and construction of new, more sinuous channel to reinstate natural fluvial form and process, with infilling of existing channel, OR
- Lower-intervention option involving creation of two-stage channel, with more sinuous low-flow channel and inset floodplains
- Can be combined with other restoration measures, including wet woodland creation, riparian zone improvements and floodplain scrapes, to maximise benefits

Advantages/Expected Positive Effects

- Restoration of natural fluvial form and process results in dynamic, self-sustaining river system (although to a lesser degree for two-stage channel option)
- Increased channel length reduces slope, thus reducing erosion of bed and banks (i.e. reverses tendency of straightened channels to continue to deepen)
- Improves sediment dynamics within the channel, reducing risk of ongoing build-up of sediment at 'pinch points' such as low bridge, thus reducing maintenance load
- Increased connectivity between channel and floodplain, restoring more natural flood dynamics and encouraging deposition of fines on floodplains, thus reducing fine sediment load in river
- Considerable benefits for in-channel and floodplain habitat, which can be enhanced by incorporating additional design features
- Flood risk benefits downstream – slows flow by increasing channel length and complexity
- Increased resilience to climate change (flood and drought) through enhanced retention of water on floodplains and improved soil health through increased deposition on floodplain
- Contributes to NRF priority themes through:
  - NFM and reconnecting rivers to floodplains
  - Restoring watercourses
  - Reducing flow
  - Increasing ponds and water/wetland habitat (if included as part of design)
  - Making more space for streams and riparian habitat
  - Adopting nature-based approaches to managing key ecosystems
  - Supporting changes in management to favour diversity of species and habitat structure

Disadvantages/Potential Negative Effects

- Increase in flooding locally as part of design objectives
- Requirement for land take/land repurposing to support measures (less land take required for two-stage channel)
- Potential for considerable disruption to existing habitat during construction
- Design and construction likely to be costly (likely less costly for two-stage channel)

Maintenance Requirements

- Some long-term maintenance may be required depending on preferred option but maintenance load likely to be reduced significantly
- Regular monitoring (e.g. by fixed point photography, repeat topographic survey) to ensure effective channel/floodplain function (recommended, but not essential)
- Monitoring of habitat improvements (recommended, but not essential)

Next Steps

- Detailed design and modelling study required, alongside regulatory considerations
- Tender for a suitably experienced contractor (considering 'working in river' window)
- Apply for funding – both design and construction phases of work may be eligible for funding

4.1.5. Wet Woodland

Wet woodlands are one of the rarest terrestrial habitats in the UK and can be found naturally in many wetland systems, including on floodplains and in riparian zones. These woodlands are waterlogged for at least part of the year and typically occur on poorly drained or seasonally wet soils, in small patches or as localised areas in larger, drier woodlands. The abundance of dead wood, combined with damp conditions, provides numerous ecological benefits, including providing habitat for insects, birds, mammals, amphibians and reptiles and helping to both store flood waters and reduce pollutant input to nearby watercourses. Wet woodlands are typically dynamic and highly responsive to environmental change. Historically, large areas of wet woodland habitat have been lost, often as a result of changes in land use, particularly due to changes in drainage (e.g. through drying out of areas to support farming or commercial forestry, or through reduction in the water table due to historical disconnection of river channels from their floodplains). Accordingly, restoration of this type of habitat is considered particularly desirable.

Wet woodland environments created within the river corridor can also provide a future source of natural large wood to the channel. Accumulation of wood in rivers enhances geomorphic process by encouraging localised bar development and associated bank erosion to induce the natural recruitment of alluvial material and, over time, further large wood to the channel. Large wood also encourages bed erosion and the development of scour pools around the woody material, offering additional refuge habitat for salmonids. The benefits of large wood is further discussed in the subsequent section (4.1.6).

Native tree planting could be carried out around the wetland scrapes proposed for Templeton Bog and the Mossat Burn (Section 4.1.3) to promote the development of wet woodland. Once established, these wet woodland areas will enhance the surface roughness of the floodplain due to the complexity of the trees themselves and the fallen deadwood. This ‘messy’ environment could help to slow the movement of water through these floodplain areas during flood events, providing NFM benefit over the longer term.

Broadleaf woodland is present along the river left bank for the lowermost ~450 m of the Auld Water. This area already presents some complexity in terms of vegetation structure and floodplain surface roughness. Extension of this woodland, carried out in combination with restoration of the channel through realignment or creation of an inset floodplain (Section 4.1.4), could enhance channel-floodplain connectivity and promote the development of a wet woodland environment within this area.

Table 4.6 Qualitative assessment of wet woodland creation

Measure	Wet woodland creation	**Location**	Auld Water, Mossat Burn, Templeton Bog
Development	**Deliverability**		**Cost**

Description

- Enhancement of existing areas of wet woodland through active management (e.g. coppicing, altering drainage to retain more water)
- Introduction of new areas of wet woodland on floodplains and/or in riparian zones, likely in conjunction with other restoration measures (e.g. improvements to channel/floodplain connectivity)
- Aims to restore natural successional processes
- Type of woodland depends on site-specific conditions but typically alder, willow or birch with sedges, ferns and mosses underneath

Advantages/Expected Positive Effects

- Restoration of rare and important habitat type, with considerable benefits for biodiversity and habitat connectivity
- Benefits for flood risk through increased storage of water and increased floodplain roughness
- Reduction in delivery of pollutants and fine sediment to watercourses
- Works well in conjunction with other restoration measures that enhance channel/floodplain connectivity
- Increased resilience to climate change (flood and drought) – increased storage of water on floodplain has potential to 'buffer' climatic extremes
- Relatively low cost compared to other restoration measures (although may require additional measures to support increased wetting)
- Contributes to NRF priority themes through:
  - NFM and reconnecting rivers to floodplains
  - Increasing ponds and water/wetland habitat
  - Making more space for native trees and ponds
  - Adopting nature-based approaches to managing key ecosystems
  - Supporting changes in management to favour diversity of species and habitat structure

Disadvantages/Potential Negative Effects

- Increase in flooding locally as part of design objectives
- Requirement for land take/land repurposing to support measures
- Potential for disruption to existing habitat during construction
- Habitat may be susceptible to pollution and climate change
- Successional change may result in eventual drying out of some areas

Maintenance Requirements

- Some long-term maintenance may be required to maintain habitat, e.g. coppicing, drainage maintenance
- Monitoring of habitat improvements and success of restoration measures (recommended, but not essential)

Next Steps

- Ecological survey to assess existing woodland habitat and advise on appropriate species for further planting
- Consider additional measures that may be required to sustain wet woodland habitat
- Apply for funding that may cover the saplings and/or planting – funding may also be available for monitoring as part of a larger project

4.1.6. Large Wood Structure Installation

The irregular structure and spatially random nature of naturally accumulated large wood in river channels promotes flow heterogeneity and bedform diversity and is important in the maintenance of a dynamic river system. Strategically placed large wood structures (LWS) are often used as a low-maintenance, self-sustaining method of developing an environment that provides suitable habitat for all stages of the salmonid life cycle (e.g. encouraging deposition and maintenance of clean gravels for spawning, sheltered backwaters for fry and faster flows for hunting parr and smolt). These structures can be positioned either at the bank or in the middle of the channel, referred to as bar apex or medial structures, respectively. A diagram illustrating the positioning of a bar apex structure within the channel bank is provided in Figure 4.8.

Figure 4.8 Illustrative example of large wood placement. Left: cross-sectional view of a channel, Right: structures installed on alternate banks.

LWS implemented in appropriate locations (and of appropriate sizes in relation to the dimensions of the channel) can help to 'kick-start' geomorphic processes and enhance available in-stream habitat. These structures encourage localised bar development and associated bank erosion to induce the natural recruitment of alluvial material and (over time and where riparian tree cover is present) large wood to the channel. Large wood also encourages bed erosion and the development of scour pools around the woody material, offering additional refuge habitat. Wood also provides localised obstruction to flow, promoting depositional processes and helping to create sheltered, shallow areas. These enhancements to physical processes, therefore, promote ecological diversity (i.e. creating a range of micro-habitats beneficial for invertebrate, plant and fish populations). Additionally, these structures are thought to contribute to climate resilience by slowing water movement, reducing flood peaks and providing cooler refuge areas (i.e. in-channel cover) for aquatic life as temperatures rise under climate change.

LWS are recommended to be introduced within straighter sections of the River Don where the deposition of proto-bars indicates the potential for enhancement of geomorphic process (Figure 4.9). Strategically placed alternate-bank bar apex structures, as shown on the right-hand side of Figure 4.8, are considered to be appropriate within these sections. The Mossat Burn would also benefit from increased geomorphic diversity through the addition of LWS. Structures should be scaled according to the watercourse channel width, such that they extend into the channel by a quarter to a third of the bank full width of the watercourse.

Figure 4.9 Example of a proto bar on the river right bank of the Don that could be enhanced through LWS installation at the upstream extent of this feature.

Anticipated benefits of LWS installation, as well as any risks, uncertainties and associated mitigation measures have been summarised within Table 4.7. This table also outlines the next steps required to implement this option and details any potential maintenance requirements following completion of the construction works.

Table 4.7 Qualitative assessment of large wood structure implementation

Measure	Large wood structures	**Location**	River Don, Mossat Burn
Development	**Deliverability**		**Cost**

Description

- LWS should be formed of natural materials, i.e. tree trunks with root plates still attached and boulders for ballast
- Structures positioned so that the base of the root plate faces upstream, into the prevailing flow, with trunk partially buried into the bed or bank and with boulders to ballast (i.e. counteract buoyancy)
- Assisted recovery approach to river restoration, designed to mimic effect of trees naturally falling into a watercourse, promoting complexity and diversity of river process
- Suitable locations should be advised by geomorphic walkover to determine geomorphologically appropriate locations

Advantages/Expected Positive Effects

These structures are designed to 'kick start' natural processes, delivering geomorphological and ecological benefits by:

- Promoting the deposition of gravels within coarser sections of riverbed material, thereby increasing the provision of salmonid spawning habitat
- Increasing heterogeneity of geomorphic features (e.g. pools, riffles or runs) in sections where modification has reduced morphological diversity
- Increasing bank and in-channel habitat diversity
- Promoting the development of a sinuous planform within the existing channel
- Creating localised hydraulic heterogeneity, with associated increase in diversity of bed substrate and available in-channel habitats
- Increasing food sources for aquatic species
- Contributes to NRF priority themes through:
  - Restoring watercourses
  - Improving in stream habitats
  - Reducing water temperature increases
  - Adopting nature-based approaches to managing key ecosystems
  - Supporting changes in management to favour diversity of species and habitat structure

Disadvantages/Potential Negative Effects

- Structures are designed to promote natural river processes, including erosion, which may be undesirable in some locations (should be considered during geomorphic walkover survey to identify suitable locations for LWS)
- Installation costs may be more expensive if materials cannot be sourced on site or locally

Maintenance Requirements

- Limited maintenance if structures are located appropriately and installed correctly, using sufficient boulder ballast
- Regular maintenance checks for damage to in-channel structures (ideally twice per year and following high-flow events), to check their stability and carry out any remedial works
- If appropriately located, correctly sized and installed, requirement and cost for remedial works generally low
- Regular monitoring (e.g. by fixed point photography) to ensure stability and effectiveness (recommended, but not essential)
- Monitoring of habitat improvements (recommended, but not essential)

Next Steps

- Geomorphic walkover to determine appropriate locations and positions of LWS
- Locate source of wood for structures and boulder ballast (e.g. windblown trees with root plate still intact from a local plantation)

- Once LWS locations have been finalised, tender for a suitably experienced contractor – works should be undertaken outside of the salmonid spawning season (September to February)
- Apply for funding – geomorphic walkover and construction phases of this work may both be eligible for funding

4.1.7. Porous Log Jam Installation

Porous log jams, also referred to as leaky log jams in the context of NFM, are structures that span the entire width of the channel (Figure 4.10). These structures are designed to mimic the natural accumulation of wood within the channel network and the resulting hydraulic and geomorphic effects of that wood. Ultimately, these structures aim to replicate the complexity of natural river systems by enhancing both physical and ecological complexity.

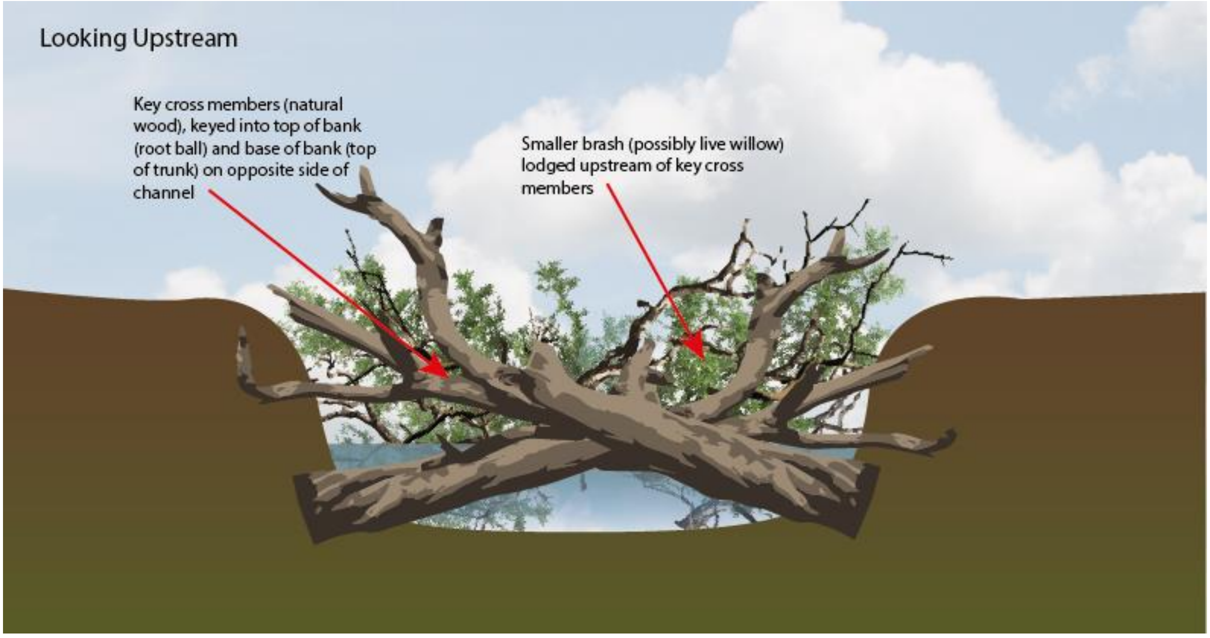


Figure 4.10 Illustrative drawing of a porous log jam, shown within a channel cross-section.

Installed at a right angle to the direction of flow, PLJs are used to increase in-channel roughness, slowing/impounding flow and encouraging water onto the floodplain under spate conditions. Ultimately, this allows for improved floodplain attenuation and reduction in downstream flood peaks. These structures are most effective if formed naturally or placed/built in series, in watercourses <5 m wide, with spacing typically recommended to be 7 to 10 times channel width to ensure channel stability (CIRIA, 2022). These structures should ideally be placed on straighter sections of channel, away from meander bends or tributary inflows. The large wood material is installed across the channel, leaving a gap between the bottom of the structure and the channel bed to allow for low flows and fish to pass relatively unimpeded.

PLJs could be installed within the Templeton Bog drainage ditch network to encourage ponding and flood water storage within this topographically confined area. This would also slow the movement of water from this area into the Auld Water and ultimately the River Don. These structures could also be installed along the Mossat Burn for NFM benefit. Development of wetland and wet woodland habitats within the Mossat floodplain could also be encouraged owing to the increased channel-floodplain connectivity that could be achieved through PLJ installation.

Anticipated benefits of PLJ installation, as well as any risks, uncertainties and associated mitigation measures have been summarised within Table 4.8. This table also outlines the next steps required to implement this option and details any potential maintenance requirements following completion of the construction works.

Table 4.8 Qualitative assessment of porous log jams

Measure	Porous log jams	**Location**	Templeton Bog, Mossat Burn
Development	**Deliverability**	**Cost**	

Description

- Large woody material installed across the channel at a right angle to the direction of flow, used to increase roughness and slow/impound flow and force water onto the floodplain under spate conditions, allowing for improved floodplain attenuation and reduction in downstream flood peak
- Can be delivered in woodland or non-woodland watercourses, gullies and ditches
- Also applicable in areas where runoff flows along defined pathways
- Most effective if formed naturally or placed/built in series, in watercourses <5 m wide, with spacing determined based on channel width and/or slope and structure height, e.g. spaced more closely within steeper channels and spread further apart within lower gradient areas
- Variable design depending on channel/hillslope characteristics and materials available
- Suitable locations should be advised by geomorphic walkover to determine geomorphologically appropriate positions for installation of PLJs and an assessment of spacing according to channel bed slope

Advantages/Expected Positive Effects

- Increased hydraulic resistance/channel roughness and increased connectivity with the floodplain, allowing for slower flows and enhanced flood water storage
- Improvements in sediment dynamics, flow diversity and water quality
- Potential stabilisation of riverbank and floodplain
- Immediate flood benefits and longer-term benefits for geomorphology/ecology
- Enhancement of habitat, directly and indirectly through trapping of sediment/wood
- Enhanced drought resilience through retention of water during dry periods
- Can be constructed using materials available on site in many cases
- Contributes to NRF priority themes through:
  - NFM by slowing flow of water and reconnecting rivers to floodplains
  - Improving in-stream and riparian habitats
  - Increasing wetland habitat on the floodplain
  - Reduce flow and sediment wash out
  - Supporting changes in management to favour diversity of species and habitat structure

Disadvantages/Potential Negative Effects

- Local increases in water levels, resulting in increased flood risk locally (mitigated through careful positioning)
- Risk of downstream structure blockage (mitigated by careful positioning)
- Potential impacts on fish and eel passage (reduced through careful design to allow low flows to pass)
- Deliverability will depend on location (e.g. access constraints)

Maintenance Requirements

- Regular monitoring (e.g. by fixed point photography) to ensure stability and effectiveness
- Regular maintenance checks for damage to in-channel structures (ideally twice per year and following high-flow events) and, where appropriate, the extra cost of repairs
- Maintenance requirements can be reduced (but not eliminated) by good design and installation

Next Steps

- Geomorphic walkover to determine appropriate locations, size and spacing of PLJs, potentially carried out alongside LWS walkover recommended in Section 4.1.6
- Locate a source of wood for the structures, e.g. windblown trees and brash from onsite or a local plantation
- Once LWS locations have been finalised, tender for a suitably experienced contractor – note that

works should be undertaken outside of the salmonid spawning season (September to February)
- Apply for funding – the geomorphic walkover and construction phases of this work may both be eligible for funding

Log jams are not recommended for installation in the River Don, due to the channel width averaging ~15 to 20 m, which is deemed too wide for this option to be effective. Although narrow enough, the Auld Water was not deemed appropriate due to the incised geometry of this channel; therefore, PLJs are unlikely to provide any channel floodplain connectivity benefit. Instead, in-channel berms may be a more effective way of promoting flow diversity within the channel.

in-channel raised benches can be installed within a watercourse such as the Auld Water to promote a more sinuous channel thalweg (position of the fastest flow within a river), promoting flow heterogeneity and habitat diversity. In plan view, these benches protrude from the bank into the channel, forming a capital 'D' shape (Figure 4.11). The outer edge is made from chestnut stakes, which are interwoven with hazel fascines and back-filled with gravels, brash and fine sediment, as shown in Figure 4.11. These features should be scaled to the channel cross-sectional size during design development, such that they influence low flow dynamics, but are 'drowned out' at bank full level and during higher flow/flooding events so as not to impact flow conveyance.

Figure 4.11 Example of an in-channel bench constructed on the right bank of this river. The top of the brushwood with chestnut stakes, forming the outer edge of the bench can just be seen above the water surface.

4.1.8. Bank Reprofiling & Green Bank Protection

Reprofiling is a management technique that seeks to improve bank stability and manage the input of fine sediment to the channel due to bank erosion, as well as promoting the development of bank side vegetation (Table 4.9). Modification of channel cross-sections to increase flow conveyance may result in over-deepened channels with steep bank sides, which are prone to instability. This can also occur where removal of riparian vegetation reduces stability that would have naturally been provided by the root networks and leaves the bank prone to erosion. Bank reprofiling is recommended in locations such as these, to lower the bank slope to a more stable gradient, for example a 1:2 slope (Figure 4.12). The increased stability of this gentler slope enables the surface to be colonised by vegetation, adding further stability to the slope over time. Once bankside vegetation is abundant, risk of further land loss is often reduced considerably. Bank reprofiling may be carried out in combination with green bank protection, riparian corridor improvements (Section 4.1.9) and set-back fencing (Section 4.1.10) to maximise the long-term stability and sustainability of this measure.

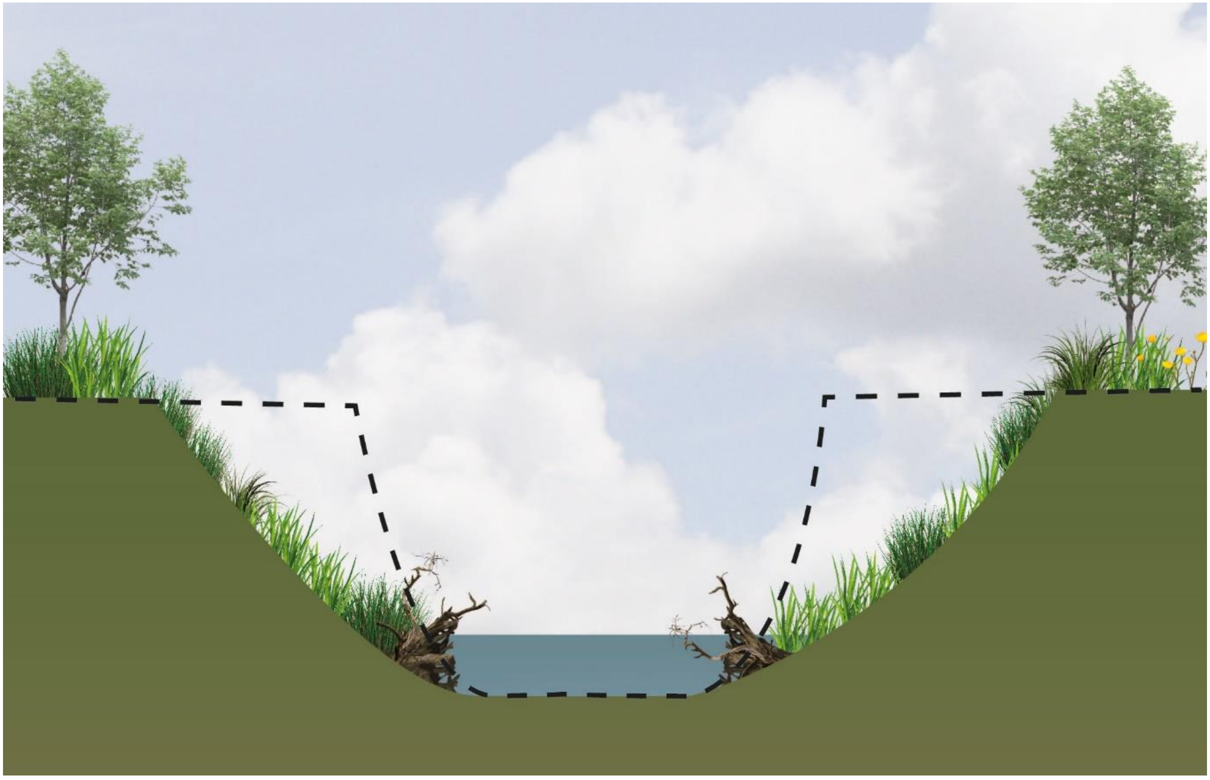


Figure 4.12 Indicative cross section indicating bank reprofiling and the installation of green bank protection.

Areas prone to erosion, such as the outer banks of meander bends, may require further stabilisation in addition to reprofiling. It should be noted that bank erosion is a natural process associated with the lateral adjustment of meandering channels, such as the section of the River Don that flows through Ardhuncart Estate. However, it is understood that bank management may be required where surrounding infrastructure or land use require further stabilisation. In such cases, green bank protection works may be carried out in combination with reprofiling. Green bank protection is an overarching category that encompasses a broad range of natural materials and works with natural processes to create a self-sustaining solution to bank erosion issues. This section will focus on the use of LWS bank protection.

LWS bank protection uses root wads positioned along the bank toe (Figure 4.13). These structures are anchored into the bank by burying their trunks and using boulders as ballast. The complex root structures dissipate energy within the flow, protecting the bank and encouraging deposition of fine sediment. Accretion of material along the base of the bank (bank toe) further develops bank stability. The processes of energy dissipation associated with this natural material contrast with hard bank protection such as concrete walls and boulder rip-rap, which deflect the energy from the water back towards the channel bed, causing erosion at the site location and elsewhere and eventually undermining this artificial bank protection.

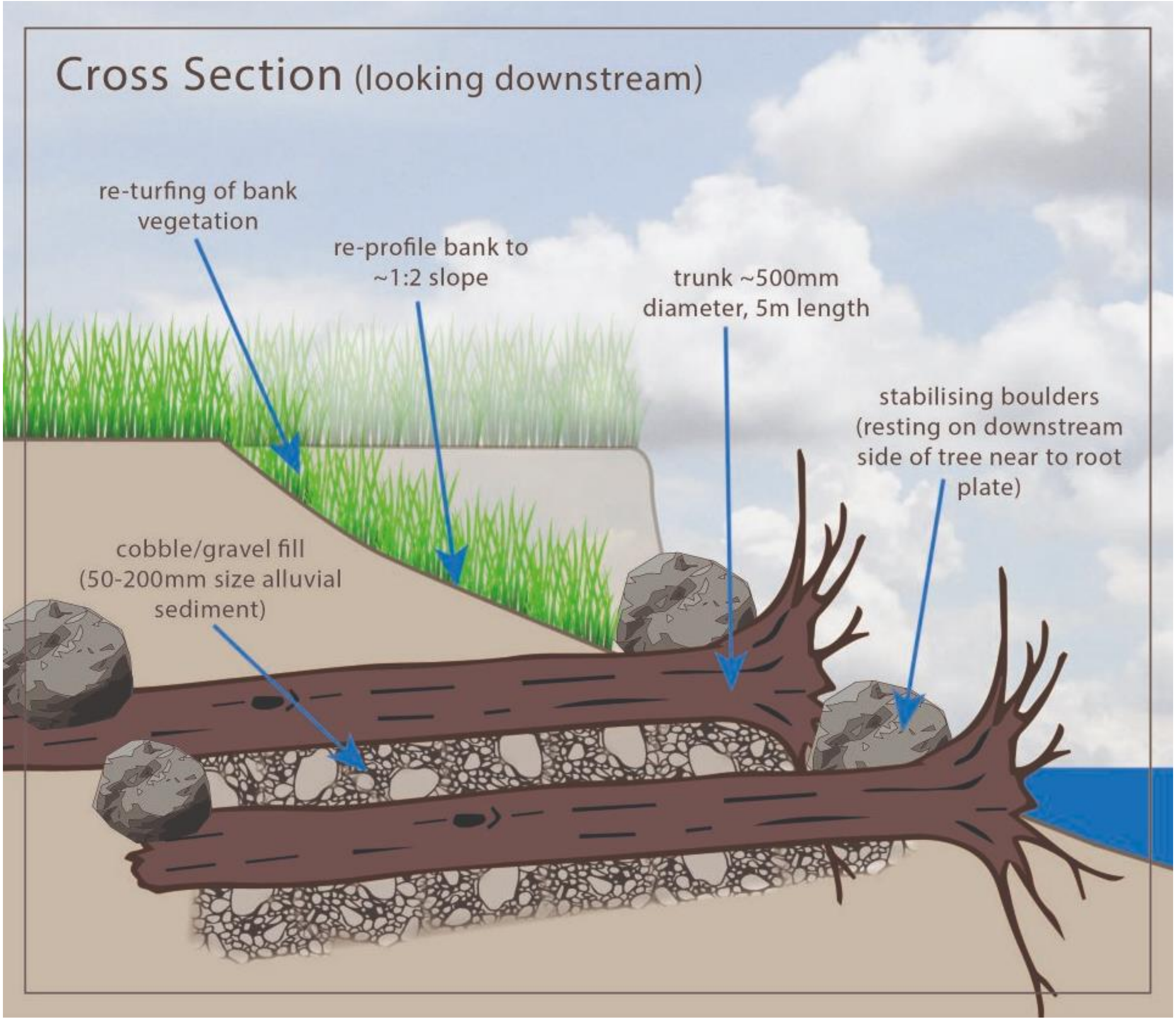


Figure 4.13 Indicative cross-sectional drawing showing the installation of LWS bank protection combined with bank reprofiling.

Reprofiling is recommended on the river left bank of the River Don, upstream of Cleek-Him-In-Pot pool (Figure 4.14) and also between Jock Reid pool and the embankment breach area (Figure 4.15), in order to increase bank stability and reduce the delivery of fine sediment to the channel. Due to the height of the latter location (where the bank height is up to ~3 m), LWS bank protection is also recommended here. Other potential green bank protection measures, including geotextile biodegradable matting and willow spilling, could also be used to tackle bank erosion across the Estate should this option be progressed to detailed design, although these additional measures have not been considered at this scoping stage of the project.

Figure 4.14 Example of bank erosion on the river left bank, upstream of Cleek-Him-In-Pot pool. Bank height is between 1 to 1.5 m at this location.

Figure 4.15 Bank erosion between Jock Reid pool and the breached embankment. The track was previously positioned between the gate/fence line and the top of the channel bank, however this route is no longer safe to access due to the erosion and embankment breach. Bank height within this section ranges from 1 to 3 m.

Table 4.9 Qualitative assessment of bank reprofiling and green bank protection

Measure	Bank reprofiling and green bank protection	**Location**	River Don
Development	**Deliverability**		**Cost**

Description

- Green bank protection to protect eroding banks where threatening assets, or to replace existing hard bank protection
- Protection to include components such as large wood structures, willow spiling, erosion control (e.g. coir) matting or other materials depending on site-specific conditions
- Reprofiling of steep eroding banks to lower, more stable gradient (making banks less prone to erosion and promote growth of stabilising vegetation)
- Qualitative assessment considers primarily bank protection comprising large wood toe protection and coir matting on bank slopes

Advantages/Expected Positive Effects

- Mitigates against bank erosion along a section of impacted bank, thus protecting nearby assets
- Reduces risk of erosion elsewhere by dissipating erosive force (rather than translating force elsewhere, as with traditional hard engineering measures)
- Promotes natural stabilisation of the channel bank over time and facilitate vegetation growth
- Reduces fine sediment input to channel
- Habitat benefits both within channel and on banks (including riparian corridor if combined with other measures)
- Contributes to NRF priority themes through:
  - Improving riparian habitats (including the channel bank and river corridor)
  - Reduce fine sediment entering the channel
  - Restoring watercourses
  - Supporting changes in management to favour diversity of species and habitat structure

Disadvantages/Potential Negative Effects

- Land take/repurposing may be required to achieve stable bank slopes (may not be possible where important assets/infrastructure present – deliverability will depend on access and other constraints)
- Reprofiling can generate significant cut material, with associated cost (can be mitigated by reusing material elsewhere on site)
- Construction can be costly, depending on materials required (can be constrained at design stage)

Maintenance Requirements

- Regular monitoring to ensure stability and where necessary remedial works (e.g. additional seeding) undertaken, particularly during period between construction and vegetation establishment, when banks most vulnerable to erosion
- Need for monitoring and maintenance can be reduced by careful design and selection of materials (although not eliminated entirely)

Next Steps

- For less complex sites, works can be undertaken by non-specialists, following standard guidance, without further design work
- More complex sites likely to require topographic survey and detailed design and modelling
- CAR licence may be required depending on proposed design and design extent
- Locate materials (e.g. trees for large wood bank protection) and tender for suitably experienced contractor (note that works should be undertaken outside of the salmonid spawning season, i.e. outwith September to February)
- May not be eligible for river restoration funding when undertaken in isolation but may be eligible as part of wider restoration works

4.1.9. Riparian Corridor Improvements

The riparian zone refers to a corridor of land that encompasses the watercourse itself and a strip of adjacent floodplain on both banks (Figure 4.16). Riparian zones are important for enhancing the provision of bank vegetation, promoting habitat diversity and bank stability, as well as aquatic habitat improvements through channel shading and contribution of large wood material to the channel. These linear zones also improve terrestrial habitat connectivity by creating a corridor that allows species to travel between existing habitat fragments. Riparian buffer strip creation can also help to mitigate increases in water temperatures and can increase resilience to climatic change by providing cooler refugia for freshwater fauna and flora. Additionally, a well-established and diverse riparian corridor can act as a protective buffer around a watercourse for both NFM and water quality purposes, intercepting surface water and nutrient run-off from the surrounding landscape. The advantages and disadvantages of this measure are set out in Table 4.10, alongside a summary of next steps required to implement this work.

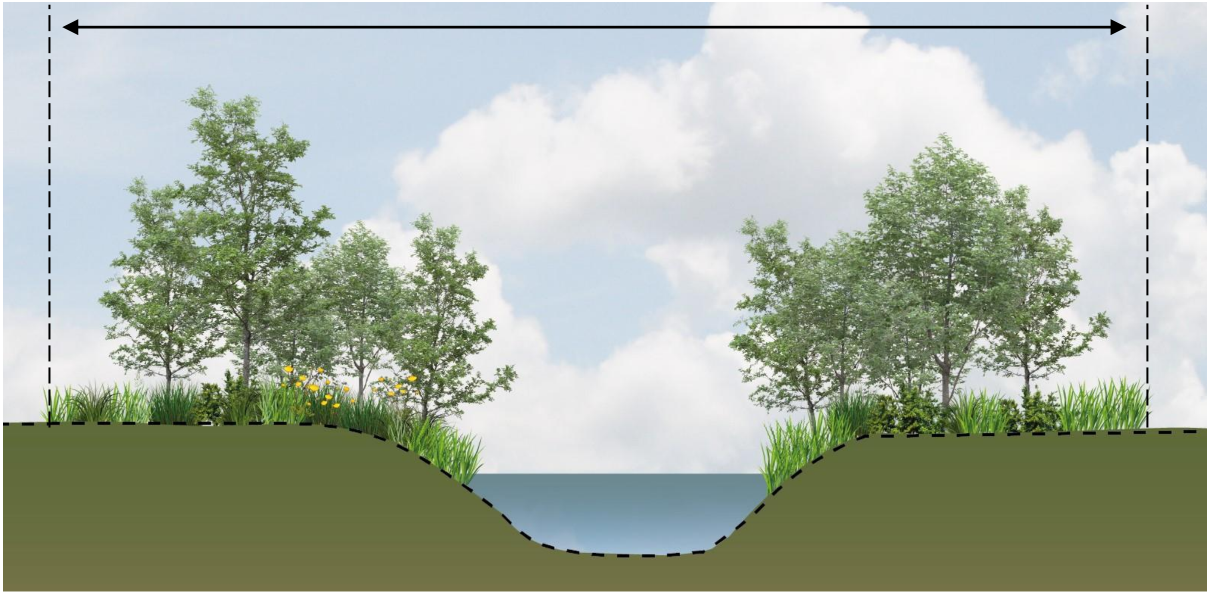


Figure 4.16 Indicative cross section illustrating improved riparian zone, with arrows indicating the full width of the riparian zone.

Within the Estate, the River Don is typically ~15 to 20 m wide, which, based on the information presented in 2.6.3, requires a riparian corridor width of ~70−80 m. It is appreciated that the financial implications of setting aside a river corridor with a width of ~30 to 40 m on either side of the channel (a total corridor width of ~70 to 80 m) may constrain the practical application of riparian improvements. Therefore, the width of the riparian corridor should be maximised where possible, within the constraints of the surrounding land use, to provide increased diversity and enhance the climate change resilience of aquatic habitats, as well as delivering water quality and NFM improvements. Specific areas outlined for planting are based on Scottish Forestry's and Marine Scotland Science's datasets (Section 2.6.3) and field observations from the geomorphic assessment (Section 3). These improvements could include planting trees or enhancing the size and/or diversity of existing riparian corridors.

To maximise the benefit of riparian planting, the Woodland Trust recommends that a mosaic approach incorporating ground flora, scrub and native tree within the corridor provides the greatest biodiversity benefits (Figure 4.17). This structure provides a mixture of shaded and lightly shaded areas to the watercourse, helping to provide lower temperature climate refugia within the channel. Water temperatures have been found to be between 2 and 3^{o}C lower where shading occurs than in the absence of riparian canopy cover.[15] This diversity of vegetation structure within the riparian corridor may also more effectively slow the movement of surface water run-off to the watercourse, increasing its NFM benefit.

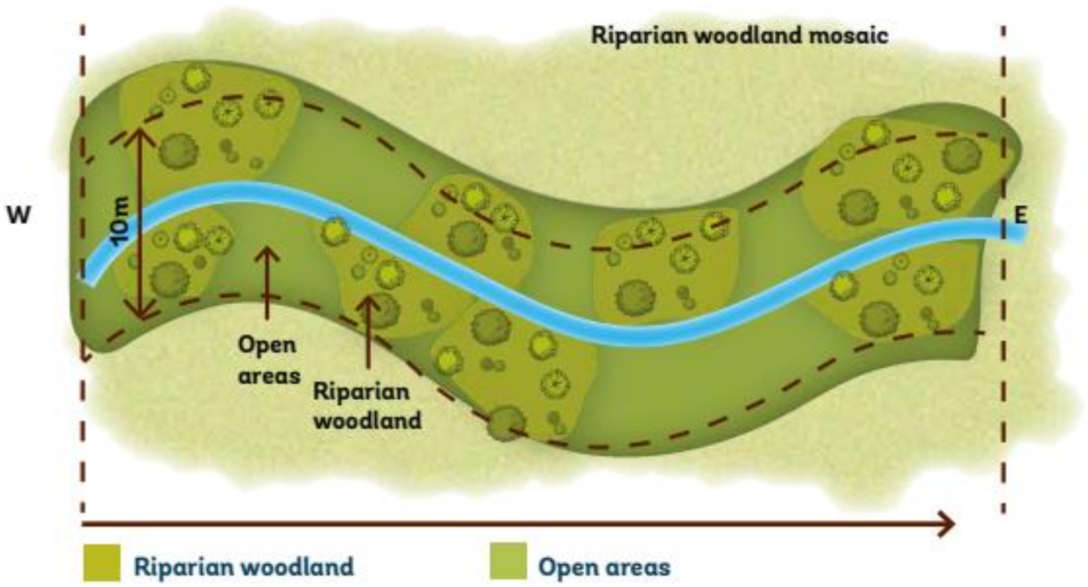


Figure 4.17 Riparian woodland mosaic recommended to provide dappled shade to the watercourse and a variety of habitats within the riparian corridor. Source: Woodland Trust (2016).[20]

Riparian corridor improvements are recommended for the River Don, Auld Water and Mossat Burn. Section of the River Don prioritised for riparian planting take into consideration opportunity areas identified by the Scottish Forestry FGS data set, aerial imagery and field observations. Areas where bank stability could be improved or reductions in run-off achieved have been prioritised, alongside creation of a more continuous wildlife corridor along the watercourse. As with the creation of riparian corridors, strips of vegetation (e.g. hedgerows or trees) can be planted along contours in areas including field margins and natural gullies to provide NFM benefit. Planting along contour lines of hillslopes can intercept flow pathways and thus reduce both surface runoff and soil erosion in agricultural land. Within the wider Estate, contour planting could be carried out to reduce the rate at which surface run-off from the surrounding hillslopes reaches the watercourse network, such as the slopes of Ardhuncart and Drumgourdrum Hills, providing NFM benefits to the Estate itself and areas further downstream. Although typically small in scale, these interventions are effective at intercepting runoff and increasing infiltration and can offer notable NFM benefits when adopted in conjunction with other measures. These practices could also be carried across to other Estates across the upper Don catchment to provide greater NFM benefits to areas downstream, including Ardhuncart Estate.

[20] Woodland Trust. 2016. Keeping Rivers Cool: A Guidance Manual - Creating riparian shade for climate change adaptation [Online]. Last accessed on 31.10.23 via https://www.woodlandtrust.org.uk/publications/2016/02/keeping-rivers-cool/

Table 4.10 Qualitative assessment of riparian corridor improvements

Measure	Riparian corridor improvements	**Location**	River Don, Auld Water, Mossat Burn
Development	**Deliverability**		**Cost**

Description

- Riparian corridor is strip of uncultivated land on either side of a watercourse, forming a wildlife corridor
- Introduce (where absent) or widen existing riparian buffer strips to approximately two times the channel width on each bank to provide watercourse with more space to adjust
- Buffer strips should include diverse range of native woodland species, advised by an ecologist

Advantages/Expected Positive Effects

- Improve habitat diversity and connectivity by providing a wildlife corridor
- Improved in-channel habitat through increased shading of the river, helping to manage summer water temperatures by providing cooler refugia for aquatic organisms – exposed tree roots may also provide additional habitat
- Provide long-term, cost-effective measure for managing bank erosion – bank stabilisation will increase as the trees mature and their root networks increase
- Help buffer surface water run-off in the lead up to flood events and reduce nutrient run-off from agricultural land – potential improvement in water quality as nutrients get trapped within the buffer zone
- Over longer term, trees planted will supply channel with woody material to promote diversity of geomorphic processes
- Increased floodplain and in-channel roughness leading to attenuation of flood flows
- Greater evapotranspiration, infiltration and interception, which will help to reduce run-off rates to channel
- Increase in carbon sequestration and storage within riparian zone
- Contributes to NRF priority themes through:
  - NFM by slowing movement of water to the channel
  - Improving riparian habitats
  - Supporting changes in management to favour diversity of species and habitat structure
  - Making more space for native trees

Disadvantages/Potential Negative Effects

- Fencing may be required to avoid livestock and deer grazing in any locations where native tree planting is proposed, incurring additional costs
- May not be compatible with other land management practices
- Trees takes time to mature so the advantages of tree planting will take time to deliver the optimum benefit, however, this may be countered by gradual climate change escalation

Maintenance Requirements

- Maintenance of deer and livestock fencing to prevent grazing of saplings and scrambler damage
- Annual pruning of trees if planted within the near vicinity of a constraint such as a road or overhead power cables (mitigated by planting being prioritised in unconstrained areas
- Monitor success of planted saplings, replacing tree guards as necessary if area not fenced

Next Steps

- Ecological survey to assess existing riparian habitat and advise on appropriate species for further planting
- Apply for funding which may cover the samplings and/or planting – funding may also be available for monitoring as part of a larger project

4.1.10. Set Back Fence Lines

Where fences run along the top of the riverbank, it is recommended that these are set back into the floodplain to provide more space for the river to adjust and the riparian corridor to develop (Figure 4.18). Offsetting fence lines can also facilitate improvements to bank stability and provide a sustainable measure for preventing against the loss of valuable farmland through bank erosion. The advantages and disadvantages of this measure are set out in Table 4.11, alongside a summary of next steps required to implement this work.

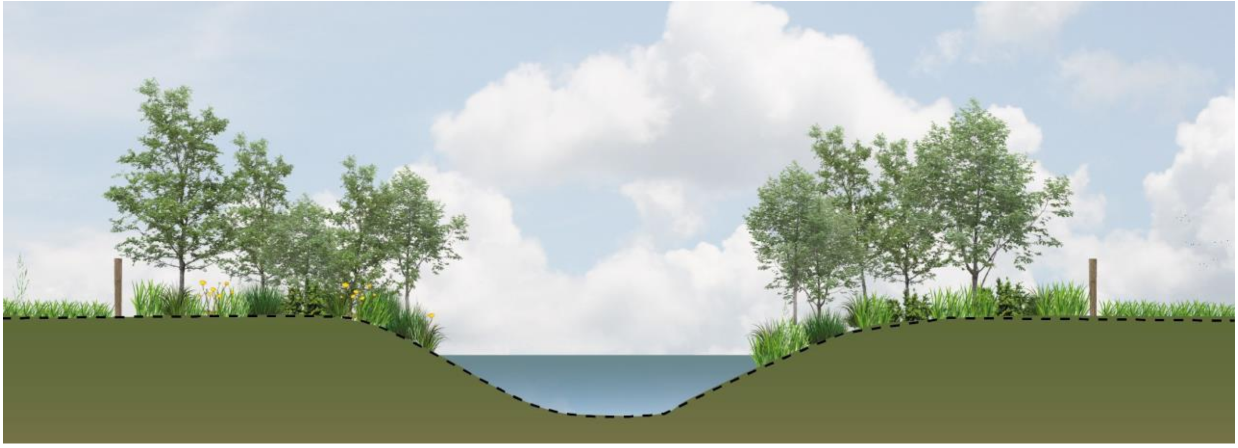


Figure 4.18 Indicative cross section illustrating setting back of fencing, combined with riparian zone improvements.

Set-back fencing falls within the riparian corridor improvements category because implementation of this measure increases the space available for bank face and buffer strip vegetation improvements (Section 4.1.9). However, not all the locations recommended for buffer strip enhancements within Ardhuncart Estate have fences; therefore, this option has been listed separately to differentiate between areas with and without this requirement. Moving fence lines back from the top of the riverbank can also improve bank stability over time, particularly when combined with bank reprofiling (Section 4.1.8). Additionally, fencing off the bank prevents livestock accessing and trampling the banks, which can erode bank material and impede the growth of vegetation cover, thus reducing the structural stability of the bank. Where riparian corridor improvements are carried out in between the top of the riverbank and the set-back fence line, the root network of trees planted can help to stabilise bank material as well as forming a buffer against soil erosion and nutrient run-off from the adjacent fields.

Sections of bank that would benefit from set-back fencing were observed along the River Don and the Auld Water. Between Jock Reid Pool and the embankment breach area, the river left fence line runs along the top of the bank (Figure 4.19). In combination with bank reprofiling and protection, setting back the fence line to create space for bank reprofiling, green protection and riparian corridor improvements is recommended to prevent the loss of agricultural land in this area. An access track runs along the top of the bank along this section towards the bridge across to Westside. This track has been cut off by the embankment breach and the bank erosion upstream is causing further instability to the remaining section of track. Following setting back of the fence line, it is recommended that this track is rerouted; however, any new route to Westside bridge should consider the work proposed to be undertaken to make the embankment breach area a flood storage zone, which may make these fields inaccessible for vehicular access. For this reason, the access track route should be considered during the detailed design of the embankment breach restoration area.

Figure 4.19 Fence line positioned along the top of the River Don right bank, next to Jock Reid pool. This section of bank is just upstream of the bank erosion and embankment breach. Recommend to set-back the fence line and reprofile the bank, to provide long-term bank stability.

The fence line along both banks of the Auld Water, within the same field as the River Don embankment breach, was noted to be leaning into the channel (Figure 4.20). This indicates bank instability that may be due in part to the over-deepening of this tributary historically to increase flow conveyance through the agricultural land and to the steep bank gradient (Figure 4.21). It is recommended that the fences are set back from the top of the bank by at least five metres to reduce the risk of further destabilisation. The area between the bank top and the newly positioned fence could be planted with native species to further improve bank stability, provide greater riparian habitat and reduce fine sediment input from overland flow. Reduction of fine sediment input to the channel via bank erosion could also help to reduce the dominance of macrophytes within the Auld Water. These fencing and riparian corridor improvements could be carried out in combination within realignment or the creation of an inset floodplain along the Auld Water (Section 4.1.4), as well as wet woodland creation (Section 4.1.5).

Figure 4.20 Fence line undermined by bank erosion on the river right bank of the Auld Water. This section of erosion is noted within the same field as the embankment breach.

Figure 4.21 Bank erosion observed on the river left bank within the same field as St. Brides Chapel. The fence line along the top of bank here is likely to be undermined in future flood events when this bank is subject to further erosion.

Table 4.11 Qualitative assessment of setting back of fencing

Measure	Set-back fencing	**Location**	River Don, Auld Water
Development	**Deliverability**		**Cost**

Description

- Move existing fences and/or install new fence lines at a set distance back from the top of the riverbank
- Ideally, fences to be set back from the river bank a distance of at least two times the channel width, to provide a sufficient riparian corridor of uncultivated land (dependent on the surrounding land-use and other site-specific constraints)
- Option can be carried out in combination with riparian corridor improvements and/or bank reprofiling

Advantages/Expected Positive Effects

- Provides space for riparian corridor development and processes of natural channel adjustment
- Reduces the risk of bank erosion by preventing livestock from trampling or disturbing this area
- Enables riparian corridor vegetation to establish, increasing bank stability, without being grazed by livestock
- Protecting bank from trampling and enabling vegetation growth increases bank stability, reducing risk of valuable agricultural land being lost through bank erosion
- Reduces risk of fine sediment (which may smother spawning gravels) entering channel by facilitating improvements in bank stability
- Contributes to NRF priority themes through:
  - Improving riparian habitats (if space is allowed for a riparian corridor between the top of bank and the new fence line)
  - Making more space for native trees (as above)

Disadvantages/Potential Negative Effects

- Cost associated with installing new fence lines
- Cost associated with land take required to set back the fence lines
- May not be compatible with other land management practices

Maintenance Requirements

- Maintenance of fencing to prevent livestock entering the riparian corridor

Next Steps

- If being carried out in combination with riparian corridor improvements or bank reprofiling, next steps for those options should be carried out first to determine required set-back distance – other works may also need to be undertaken prior to fence line being erected to facilitate machinery access to channel
- Discuss set back distance with landowner(s) and/or tenant(s), to determine their amenability
- Funding unlikely to be available for options if undertaken alone but may be available if included as part of a larger multi-option restoration project

4.1.11. Bridge Alterations

A field access bridge across the Auld Water was noted to have a low soffit level and had become blocked by silt build-up, which is causing water to back up behind the structure. Alterations to the bridge could be carried out in combination with realignment of the Auld Water, to improve flow and sediment conveyance through the watercourse. Bridge alterations could also reduce constriction of flow and/or likelihood of this structure being blocked by debris during flood events.

Table 4.12 Qualitative assessment of bridge alterations

Measure	Bridge alterations	**Location**	Auld Water
Development	**Deliverability**		**Cost**

Description

- Bridge alterations are proposed where the bridge shape, abutment position and/or soffit level are impacting the natural functioning of hydrological or sedimentological river processes.

Advantages/Expected Positive Effects

- Improves flow conveyance under bank full conditions.
- Improves the movement of sediment through the channel, preventing accumulation of material upstream blocking the bridge.
- Opportunity to improve existing access between fields.
- Contributes to NRF priority themes through:
  - Improving in-stream habitat
  - Restoring watercourses (if carried out in conjunction with realignment or creation of an inset floodplain along the Auld Water, see Table 4.5).

Disadvantages/Potential Negative Effects

- Cost associated with design and installation of new bridge.
- Disturbance to agricultural practices whilst new bridge is installed (mitigated by consulting the landowner and/or tenant about timings).
- Suitability of bridge for access by all required farming machinery (mitigated by appropriate design considerations).
- Suitability of bridge for facilitating movement of flow during high flood events.

Maintenance Requirements

- Maintenance of bridge is dependent on materials used in construction.
- If designed appropriately, maintenance requirements should be less frequent than the existing structure as blockages and damage during flood events less likely

Next Steps

- Discuss bridge alterations with the landowner(s) and/or tenant(s), to determine their amenability.
- Funding is unlikely to be available for this option alone but may be available if included as part of a larger multi-option restoration project.
- If being carried out in combination with realignment or creation of an inset floodplain along the Auld water, design development of these measures will need to be carried out prior to the bridge improvements. However, these elements and the bridge alterations could be undertaken together in the subsequent construction phase.

4.1.12. Weir Removal

Weirs are artificial in-channel structures which span the width of a watercourse and are typically used as a grade control or to maintain a head of water for industrial purposes such as hydropower or milling. These structures are designed to provide industrial or infrastructural benefits; however they also inhibit natural geomorphic processes such as the transfer of sediment and water downstream through a river system. Weirs can also act as barriers to fish passage making it difficult for or, in many cases completely preventing, migratory fish from reaching suitable spawning habitat in upstream reaches. Where these structures are redundant, either partial or full weir removal is recommended to improve the longitudinal connectivity of a watercourse, delivering both ecological and geomorphic benefits. Alternatively, in situations where such structures are still required for industrial or other purposes, they can be altered through measures such as creating a lower notch within the weir crest or through the installation of features onto the apron to provide a preferential flow route for fish passage. However, these lower levels of intervention do not provide benefits to the restoration of geomorphological processes.

A boulder weir is located at OS NGR NJ 48849 18692 on the Mossat Burn. This weir is thought to be associated with the Invermossat Mill and would have originally been installed to maintain a sufficient head of water upstream of the structure to feed the mill lade offtake on the river right bank, powering the mill. Given the state of disrepair of this boulder weir, it is assumed that this structure is no longer in use. Therefore full removal of this structure is recommended to restore the natural transfer of sediment and flow through this section of the burn. Whilst this structure was not noted by the Don DSFB in the Mossat Burn habitat improvements report, suggesting that it does not form a barrier to fish passage, removal of structure remnants such as this still aid the migration of fish to areas further upstream. Before and after visualisations of how the Mossat Burn may look if weir removal were undertaken are provided in Figure 4.22 and Figure 4.23, respectively.

The entrance to the mill lade is blocked by boulders, but during weir removal this material could also be removed and the channel bed at the upstream end of this side-channel regraded, to connect it with the Mossat Burn. Although historically constructed as a mill lade, the reconnection and naturalisation of this channel would increase the flow capacity of the Mossat Burn and provide additional areas of in-channel habitat. Further information about side-channel reconnection is provided in Section 4.1.1.

Figure 4.22 Looking downstream towards the boulder weir on the Mossat Burn.

Figure 4.23 Visualisation showing how the Mossat burn may look following weir removal and installation of LWS.

Table 4.13 Qualitative assessment of weir removal

Measure	Weir removal	**Location**	Mossat Burn
Development	**Deliverability**		**Cost**

Description

- Weirs are artificial structures constructed within watercourses to act as a grade control or to encourage a backwater effect in order to maintain a sufficient head of water to power a piece of machinery for example a water wheel of a mill.
- Weirs interrupt the transfer of flow and sediment longitudinally through a river system, as well as affecting fish passage.
- The existing structure may be altered, or additional features added to improve fish passage across the weir.
- Alternatively, partial or full removal of the weir structure may be carried out. Where weirs are no longer in use, full removal is preferable to restore natural functionality of river processes and fish passage.

Advantages/Expected Positive Effects

- Re-establish longitudinal connectivity, thereby improving fish passage upstream of the structure.
- Allow natural geomorphic processes (e.g. longitudinal sediment transport) to resume.
- Weirs can cause scour of the bed and banks downstream of the structure; accordingly, removal can also increase channel stability.
- Avoid potential for sudden failure of structure in future.
- Contributes to NRF priority themes through:
  - Restoring watercourses
  - Improving in-stream habitats
  - Supporting changes in management to favour diversity of species and habitat structure

Disadvantages/Potential Negative Effects

- Risk of channel instability following removal, especially if used as a grade control (mitigated by design and modelling of removal options).
- Feature may be of archaeological or heritage value (relevant groups should be consulted prior to removal)

Maintenance Requirements

- Regular maintenance checks for damage to in-channel structures (ideally twice per year and following high-flow events), to check their stability and carry out any remedial works.
- Maintenance work can be reduced, but not eliminated if by the development of a geomorphologically appropriate design and the quality of construction works.

Next Steps

- Consultation with local archaeological and heritage groups/organisations to determine heritage value of the structure and potential for removal. For example, if low value, a photographic survey of the structure to log its existence may be required prior to removal.
- Appoint suitably qualified consultant to undertake detailed design for the weir removal and remedial works to stabilise channel post-demolition.
- Topographic survey of the weir, as well as adjacent section of channel and floodplain may be required to facilitate any hydraulic modelling required for design development and flood risk assessments.
- Apply for SEPA CAR licence to enable in-channel works to be undertaken.
- Appoint a suitably qualified and experienced contractor to undertake works.
- Apply for funding to undertake detailed design and construction phases of work.

4.1.13. Catchment Study

The cumulative effect of implementing multiple opportunities across a catchment will have much greater benefits in terms of Natural Flood Management and Water Framework Directive objectives than implementing measures in isolation (Figure 4.24). Accordingly, this Ardhuncart Estate scoping study could be expanded to encompass a catchment-scale assessment of restoration potential. Such a study would include both desk- and field-based assessments to provide a shortlist of work packages that could be undertaken in future. This would ultimately enable the development of a strategic catchment-scale approach to natural flood management, river restoration and ecological improvements within the Don catchment. These opportunities identified could then be utilised to inform funding applications for further design and modelling work and/or implementation.

The Mossat Burn habitat restoration report indicated that changes to land-use within the catchment of this tributary has increased the rate at which surface water and sediment are reaching the watercourse (Section 2.6.4). This indicates the importance of and need for a catchment scale study that focuses, not only on the River Don itself, but also major tributaries, prioritising those with the largest catchment areas or which have undergone the greatest change in land management. This study should be guided by changes in land use, land management and hydrological functionality of the Don catchment, as well as existing data sets such as SEPA's NFM Opportunities map and River Don River Management Plan. Combining multiple sources of information will aid the identification of target areas where flood management measures could be implemented to maximise their effect.

According to the Don DSFB website, the River Don is 135 km long and drains a catchment area of 1,312 km2.[21] Given the size of the Don catchment it may be more cost effective to focus on the upper catchment, or specific estates initially, expanding more widely as landowner amenability dictates. This Scoping Study has considered options within the Ardhuncart Estate only; however, it is the cumulative effect of multiple measures being implemented across the catchment that will deliver the greatest benefit for flood risk attenuation. Accordingly, it is important to consider the spatial distribution of restoration and management measures. The opportunities identified within this report alone are unlikely to be sufficient to tackle the flooding experienced within the Estate. It can be inferred that these are the result of a combination of factors including the physical condition of the catchment (topography and geology), land management including changes to vegetation cover and drainage network enhancement within the upper catchment as well as the increasing impacts of climatic change. Therefore, it is recommended that a catchment-scale scoping study is undertaken for the upper Don catchment (i.e., upstream of Ardhuncart Estate) to identify wider NFM opportunities which could benefit the Estate as well as Alford and other areas within the lower catchment.

[21] Don District Salmon Fisheries Board. 2023. Homepage [Online]. Last accessed 30.11.23 via https://riverdon.org/

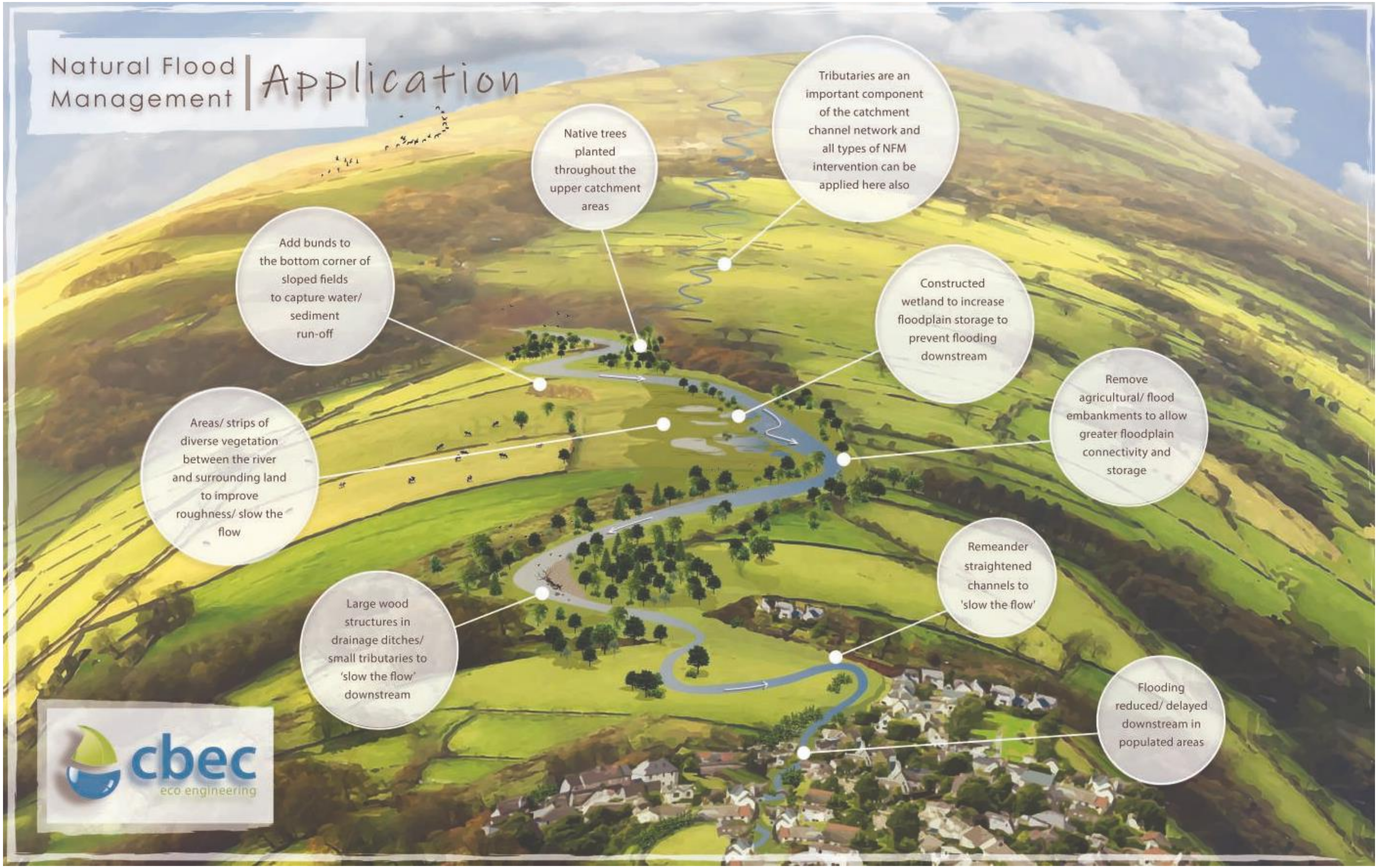


Figure 4.24 Example measures which could contribute to a catchment scale approach to Natural Flood Management.

Table 4.14 Qualitative assessment of a catchment study.

Measure	Catchment-scale scoping study	**Location**	River Don, its tributaries and the wider catchment landscape
Development	**Deliverability**		**Cost**

Description

- Study to identify potential river restoration, habitat improvement and natural flood management opportunities across the River Don catchment.
- Assessment could be undertaken for the whole catchment, a section of the catchment (e.g. upper catchment) or for a collection of interested landowners.
- Opportunities identified within the scoping study could be used as potential projects for funding applications.
- NFM measures are modelled to be most effective when multiple measures are carried out over a wide spatial scale, for example the whole upper catchment of the River Don, to maximise the flood attenuation effect.
- Catchment study should include both desk-based assessment and targeted geomorphic walkover ensuring appropriateness of opportunities identified.

Advantages/Expected Positive Effects

- Identifies multiple potential opportunities benefiting a wider area of the river/catchment.
- Opportunities could be used to advise future funding applications.
- Provides a catchment scale approach to flood management. Proven to be more effective that at an individual reach scale.
- May facilitate partnerships between landowners to achieve mutual goals or deliver work that spans across landownership boundaries.
- Contributes to NRF priority themes through:
  - NFM and surface water management solutions, including reconnecting rivers to floodplains
  - Restoring watercourses
  - Improving in-stream and riparian habitats
  - Increasing ponds and water/wetland habitat
  - Supporting changes in management to favour diversity of species and habitat structure

Disadvantages/Potential Negative Effects

- Cost associated with full catchment-scale assessment (mitigated by targeting either the upper catchment or a select group of interested, ideally neighbouring landowners).
- Requires access permission from multiple landowners to facilitate the targeted geomorphic walkover.

Maintenance Requirements

- Would be determined through the study.

Next Steps

- Consultation with:
  - neighbouring and wider landowners to determine the level of interest within the catchment.
  - interested parties such as the Don District Salmon Fisheries Board to identify if any partnerships on new or existing projects could be made.
  - Potential funders, such as NatureScot to determine if financial support for this catchment-scale assessment may be available.
- Appointment of suitably qualified consultant to undertake catchment study.
- Landowner and community engagement meeting following identification of options to assess options and pave the way forward.

4.2 OPTION AREAS SHORTLIST

Following the geomorphic assessment of the study site and consideration of the longlisted options, a shortlist of eleven site-specific 'Option Areas' considered to have potential for implementation of restoration, NFM and/or management measures, have been produced. Each of these Option Areas is intended to be a defined work package that can be taken forward to concept/detailed design and/or construction, either in isolation or in conjunction with other work packages. In addition to these site-specific Option Areas identified within the Estate, a catchment-scale study is also recommended to identify NFM opportunities across the wider River Don drainage basin.

It is important to note that this shortlist does not provide an exhaustive list of all potential options within the Estate. Rather, this shortlist represents site-specific options considered to have good potential for future works without a requirement for any additional scoping work to be undertaken.

Options have been numbered in an upstream to downstream direction along the River Don, followed by its tributaries and are presented in Figure 4.25 and Table 4.15.

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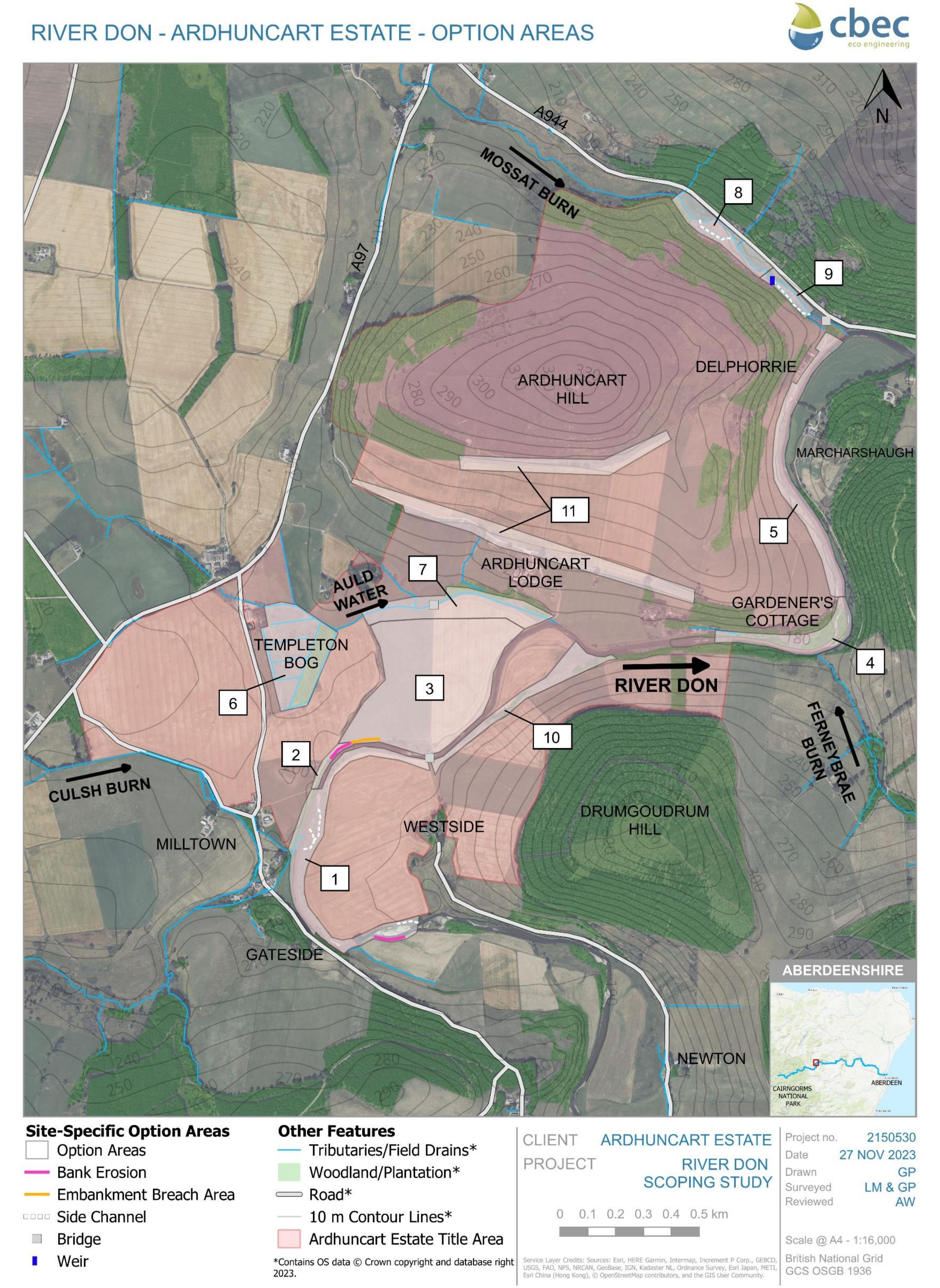

Figure 4.25 Site-specific option areas identified within the Ardhuncart Estate.

Table 4.15 Short-list of option areas identified within the Ardhuncart Estate

Area Number	Location	Options	Constraints
River Don			
1	Cleek-Him-In-Pot to Jock Reid pool	▪ **Large Wood Structures** installation on alternate banks to promote the development of proto-bar features (indicators of depositional areas within the channel bed) noted during the walkover. ▪ **Embankment/wall partial or full removal** on the river right bank to improve connectivity with the floodplain. This option could also improve drainage of flood waters from agricultural fields behind this linear feature following higher flows. ▪ **Side channel reconnection** on the river right bank opposite Nether Kildrummy to improve flow capacity and enhance habitat provision. ▪ **Riparian corridor Improvements.** Carry out targeted planting within the uncultivated strip of land on both sides of the channel, extending to two times the channel width where possible to maximise the biodiversity and surface run-off buffer effect. ▪ **Bank reprofiling** of the eroded bank to a more stable gradient, to mitigate against further loss of material.	▪ Buildings on the river left side of the channel. Positioning of LWS should consider the effects of any resultant channel migration on these properties. ▪ Overhead utilities run along the river left bank near Milltown and cross perpendicular to the channel within this reach. ▪ Entrenched channel cross-section of the River Don may make it technically challenging to reconnect secondary channels. ▪ Land take along the river corridor would be required to undertake the riparian improvements proposed within this area.
2	Section of bank erosion between Jock Reid pool to embankment breach	▪ **Bank reprofiling** of the eroded bank to a more stable gradient, to mitigate against further loss of material. ▪ **Green bank protection.** Erosion is most prominent on the outer bank of a meander bend, such as this location. Considering these erosional processes and the friable bank material present, it is recommended that green bank protection is implemented at this location to improve bank stability and offer a more sustainable solution to managing the issue in the longer term. ▪ **Set back fence line** to provide space for bank protection and riparian improvement works. ▪ **Riparian corridor improvements** between the set back fence line and the riverbank to further promote bank stability and improve	▪ Access track along this bank would need to be rerouted. ▪ Bank works, riparian improvements and fence setting back would require agricultural land take.

		habitat diversity. ▪ **Set back access track** to provide space for bank protection and riparian improvement works.	
3	Breached embankment area between Jock Reid pool and the Auld Water confluence	▪ **Embankment alterations** – partial breach or full removal of embankments along the river left bank of the River Don within this section to enhance floodplain inundation. These areas are indicated by the SEPA NFM opportunities mapping as medium to high priority for floodplain storage. Enabling increased inundation of these areas during flood events and careful selection of embankment breach points (using an iterative design modelling approach) to slow the movement of water back into the Don at the downstream end of this area could help to reduce flooding within the narrower section of valley downstream of Ardhuncart Lodge. ▪ **Side channel creation** to increase capacity during flood events. This channel would be positioned following the path of floodwater inundation and guided by historic channels visible within aerial imagery of the Estate, in order to function effectively within the hydrology of the site. The channel would be designed to inundate at high and flood flows and to provide additional habitat within the floodplain. Hydraulic modelling would be required to determine appropriate channel geometry and maximise the benefit of this design feature. ▪ **Large Wood Structures** positioned on the floodplain as a lower intervention alternative to side channel creation. These structures would be installed in strategic locations, within the paths of floodwater inundation and historic channels visible within aerial imagery of the floodplain and anchored within the floodplain. Ultimately, designed to increase surface friction, slowing the movement of water across the floodplain during flood events. These may also encourage localised scour around the structures encouraging surface water ponding following flood water recedence which may provide good habitat for wetland species and wading birds.	▪ Loss of agricultural land. These opportunities would increase flooding to the agricultural fields within this area, in order to contribute towards reducing flood risk downstream. ▪ Source of material for the large wood structures.

3 (Continued)	Breached embankment area between Jock Reid pool and the Auld Water confluence	▪ **Floodplain scrapes and ponds** could be excavated within the floodplain to further enhance the scour pools created around the floodplain LWS and increase the flood water retention within this area. ▪ **Riparian corridor improvements** Carry out planting along the riverbank, extending to two times the channel width where possible to maximise the biodiversity and surface run-off buffer effect. This planting will help to slow the movement of water from the floodplain back into the channel during flood events. Planting could also be carried out across the wider floodplain to increase surface roughness and slow the movement of flood water through this area whilst also aiding habitat connectivity across the Estate.	
4	Garages to Gardener's Cottage	▪ **Floodplain scrapes** within the river left floodplain (where grass paths are currently cut through rough grassland) with associated planting of scattered trees. The channel bank height is between 1-1.5 m. This, combined with anecdotal evidence from recent flood events, indicates that the Don is well connected with its floodplain on the river right bank at this location. Introducing scrapes here would encourage surface water ponding and the creation of wetland habitat. Whilst the potential for habitat enhancements from this measure are high, the flood benefit is likely to be low given the level of inundation experienced within this area. ▪ **Riparian corridor improvements.** Carry out planting along the riverbank, extending to two times the channel width where possible to maximise the biodiversity and surface run-off buffer effect. ▪ **Large Wood Structures.** Installation of medial structures (located in the centre of the channel and anchored into the channel bed) are recommended throughout the Estate to improve habitat and encourage deposition of fine grade sediment (e.g. gravels). A LWS survey should be undertaken by a suitability qualified consultant to identify geomorphologically appropriate locations for these structures with sensitivity to the constraints of surrounding infrastructure.	▪ Land take along the river corridor would be required to undertake the riparian improvements and floodplain scrapes proposed within this area. ▪ Source of material for the large wood structures.

5	Gardener's Cottage to Mossat Burn Confluence	▪ **Riparian corridor improvements.** Carry out planting along the riverbank, extending to two times the channel width where possible to maximise the biodiversity and surface run-off buffer effect. ▪ **Large Wood Structures.** Installation of medial structures (located in the centre of the channel) and bar apex structures (positioned next to the channel bank) are recommended throughout this section to improve in-channel habitat and encourage deposition of fine grade sediment (e.g. gravels). Some proto bars were noted along this section which could also be enhanced. A LWS survey should be undertaken by a suitability qualified consultant to identify geomorphologically appropriate locations for these structures with sensitivity to the constraints of surrounding infrastructure.	▪ Limited space for riparian corridor improvements available between the track and the River Don. If the track was moved to higher ground the benefits of this opportunity will increase. ▪ Land take along the river corridor would be required to undertake the riparian improvements proposed within this area. ▪ Source of material for the large wood structures. ▪ Access track along the river left bank of the channel throughout this reach and track on river right bank downstream to Macharshaugh. ▪ Bridge between Delphorrie and Macharshaugh.
Auld Water and Templeton Bog			
6	Templeton Bog	▪ **Porous Log Jams** within the ditches to slow the drainage of water from this area into the Auld Water. These structures would also encourage increased channel-floodplain connectivity and surface water ponding. The Auld Water is a minor tributary within the River Don catchment. Therefore, retaining water within Templeton Bog could lower the flood risk within the Auld Water, but is likely to have a smaller impact on flood risk of the Don. NFM is most effect when multiple measures are implemented to deliver a cumulative effect, thus this opportunity could be combined with other option outlined in this table to increase the flood benefit. Flood modelling would be required to determine the level of flood benefit. ▪ **Floodplain scrapes** to increase the floodplain storage capacity of the bog and to promote the creation of a variety of habitats associated with different levels of water inundation. ▪ **Wet woodland creation.** A strip of broadleaf woodland is present on the southeastern side of Templeton Bog. Ditch blocking could promote the development of wet woodland within this area. However, an ecology survey should be undertaken to assess the compatibility of the tree species present with intermittently submerged and/or waterlogged conditions.	▪ Source of material for the porous log jams. ▪ Ecological constraints in relation to the suitability of broadleaf tree species present, to waterlogged conditions. ▪ Would provide a temporary store of water, slowing the movement of water through the Auld Water. However, given the catchment size of this watercourse, the impact of this would be relatively minor in terms of flood risk. The ecological value would be greater, restoring the natural bog environment here within this topographically constrained area.

6 (Continued)		▪ **Riparian corridor improvements.** Planting of native, water-tolerant tree species across the remainder of Templeton Bog could promote the development of wet woodland habitat. Water tolerant trees include Willow, Aspen and Alder.	
7	Between Bear Lodge and the Auld Water-Don confluence.	▪ **Inset floodplain.** Land on either side of the Auld Water, within this section, is indicated as medium to high floodplain storage potential according to SEPA modelling. Considering the incised channel cross-section, increase floodplain storage would be most effectively achieved through widening of the channel corridor to form an inset floodplain. ▪ **Channel realignment.** As an alternative to inset floodplain creation, involving a higher level of intervention the Auld water could be realigned to sinuous planform. Historic maps from the late 1800s show that this section of channel has been straightened for the last ~150 years. The realignment would have a more natural channel cross-sectional shape promoting increased channel-floodplain connectivity during flood events. The increased sinuosity of the channel would also act to slow the flow of water through the channel to the Don, when compared with the current channel geometry. ▪ **Riparian corridor improvements.** The Auld Water is largely absent of riparian vegetation, with agricultural land extending up to the top of bank, expect for the lowermost ~450 m of the river left bank on the approach to the Don confluence. Riparian planting is recommended along this watercourse to reduce fine sediment and nutrient run-off from the surrounding land entering the watercourse. Planting on the river right bank may also slow the movement of water from the proposed flood storage zone (Option Area 3) back into the watercourse network during a flood event, potentially reducing the impact downstream. Hydraulic modelling would be required to quantify the effect of this NFM on flood risk. ▪ **Set back fence lines** along both banks within the River Don floodplain. Fencing was noted to be running along the top of bank of	▪ Land take along the river corridor would be required to undertake the proposed options within this area. ▪ Disturbance to agricultural practices.

7 (Continued)	Between Bear Lodge and the Auld Water Don confluence.	the Auld water. These fence lines are prone to collapse from bank erosion due to the over deepened cross-sectional geometry of the channel. Set-back the fence lines on both banks and carry out riparian planting to improve bank stability and prevent loss of land. ▪ **Wet woodland creation.** Increased channel floodplain connectivity, through channel realignment, could encourage the development of wet woodland within the existing woodland along the lowermost ~450 m of the river left bank and in new areas of riparian planting. ▪ **Bridge alterations** to track crossing the Auld Water at OS NGR NJ 47625 17526. Improve flow and sediment conveyance through the watercourse, as well as reducing the risk of this structure being blocked by debris during flood events.	
Mossat Burn			
8	Between where the Estate Boundary crosses the Mossat and the boulder weir	▪ **Porous Log Jams and Large Wood Structures installation** to encourage deposition of finer grade sediment (e.g. gravels) and increase flow heterogeneity within channel. These structures may also improve channel-floodplain connectivity, promoting wetland creation and slowing the movement of water through this tributary. Additionally, LWS could encourage natural restoration of a more sinuous planform within straightened sections of the Mossat Burn. ▪ **Floodplain scrapes** to enhance surface water ponding and the provision of wetland habitat within this floodplain. ▪ **Side channel reconnection** to the historic mill lade on the river right side of the channel. Although originally constructed as an artificial watercourse, this channel could be reconnected and naturalised to increase in-channel habitat availability within the lower Mossat. ▪ **Riparian corridor improvements** selectively positioned to avoid impacting overhead utilities. Shading of the Mossat Burn was a habitat improvement recommendation made by the Don DSFB (Section 2.6.7), which has been further emphasised by the burn's classification as a high priority for riparian planting to reduce water temperatures by Marine Scotland Science's analysis of the Scottish River Temperature Network data (Section 2.6.6). Riparian planting	▪ Overhead utilities. ▪ Road on the northern side of the watercourse. Positioned within the valley side, at a higher elevation that the floodplain, so unlikely to be affected. ▪ Ardhuncart Estate land boundary encompasses the river right bank only. Collaboration of landowners would be required to action this work.
8	Between where		

(Continued)	the Estate Boundary crosses the Mossat and the boulder weir	within the Mossat Burn corridor and wider floodplain would be beneficial for both habitat diversity, promoting **wet woodland** development, and increased ground surface roughness. The latter could help slow the movement of water through this tributary to the River Don during flood events.	
9	Boulder Weir to the Mossat-Don confluence	Same as Option Area 8, plus: ▪ **Boulder weir** removal to restore longitudinal connectivity of flow and sediment within the Burn. ▪ **Side channel reconnection** by removing boulders blocking the inlet, just upstream of the weir. As mentioned in relation to the side-channel in Option Area 8, this second side-channel was also constructed as a mill lade, but could be naturalised to increase habitat provision and increase geomorphological complexity.	▪ Overhead utilities. ▪ Local heritage significance of weir. Local archaeological group(s) should be consulted prior to removal. ▪ Arhuncart access road bridge located at the downstream end of this Option Area.
Wider Landscape of the Estate			
10	Near Drumgourdrum Hill	▪ **Contour planting** along the field boundaries at the base of the hill, on the northwest side. Limited vegetation cover is present within this area which may impact surface run-off. Planting along the contours of the hill will increase surface roughness, slowing the movement of surface water to the River Don.	▪ Land take along the field margins would be required to undertake the contour planting within this area.
11	Ardhuncart Hill	▪ **Contour Planting** along field boundaries which cross the southern slopes of Ardhuncart Hill. Limited vegetation cover is present within this area which may impact surface run-off. Planting along the contours of the hill will increase surface roughness, slowing the movement of surface water to the Auld Water and River Don.	▪ Land take along the field margins would be required to undertake the contour planting within this area.
Don Catchment			
12	Wider Don Catchment	▪ **Catchment-Scale Study** required to identify opportunities for NFM, river restoration and biodiversity enhancements throughout the wider River Don Catchment.	▪ Landowner interest. ▪ Size of the catchment. It is recommended that the study focuses on the Upper Don catchment, or a group of interested landowners initially to maximise the cost-benefit of undertaken this type of study.

4.3 PRIORITISATION OF SHORTLISTED OPTIONS

Despite the plentiful opportunities for restoration, management and NFM measures throughout the Arhuncart Estate, the implementation of these opportunities is likely to be affected by various constraints, including amenability of tenant farmers, availability of funding and infrastructural assets such as overhead utilities. Following discussions with the landowner, opportunities that could alleviate flood risk to the lower half of the Estate should be prioritised. In the upstream half of the Estate, where the floodplain is wider and presents a medium to high priority for floodplain storage according to SEPA modelling, the following work packages could be implemented in combination to maximise the potential NFM benefit:

- Option Area 3: Breached embankment area between Jock Reid pool and the Auld Water confluence
- Option Area 6: Templeton Bog
- Option Area 7: Between Bear Lodge and the Auld Water-Don confluence.

The photograph presented in Figure 4.26 shows these areas under the current land management at the Estate. Figure 4.27 illustrates how this area of the estate may function if these three opportunity areas were implemented. Progression of these priority areas would require detailed design development and hydraulic modelling to determine the most geomorphologically appropriate design and quantify the flood risk benefit.

In addition to these priority areas, LWS and PLJ installation are low intervention works that would enhance existing good habitat and/or further promote natural recovery of the river channel at relatively low cost. A walkover to identify suitable locations for installation within options Areas 1, 4, 5, 8 and 9, followed by construction of these structures. This work could be carried out in combination with woodland improvements across the Estate, utilising the removed trees (with root plates still intact) to form the LWS structures. Additionally riparian corridor improvements could also be progressed as part of the wide Woodland management plan for the Estate. However, planting in areas where in-channel works such as LWS structure installation, realignment, side channel reconnection and weir removal should be avoided until after the channel restoration has been completed to avoid damage to saplings or associated fencing during construction works.

Furthermore, this Ardhuncart Estate scoping study has highlighted a requirement for a wider, catchment-scale assessment of the River Don to be undertaken. This study would seek to identify NFM, river restoration and ecological improvements considering both the modifications of the watercourse network and the wider land management across the catchment. Effect NFM requires a catchment-scale approach, where individual measures may only provide a minor impact on flood peak attenuation, however it is the cumulative effect of multiple measure implemented across a catchment that is found to have the greatest flood risk benefit.

Figure 4.26 Floodplain between the embankment breach and the Auld Water confluence (Option Area 3).

Figure 4.27 Floodplain between the embankment breach and the Auld Water confluence (Option Area 3). Visualisation showing how this area may look with side channel creation, LWS and scrapes on the floodplain as well as riparian corridor improvements.

5. SUMMARY

Flooding from the River Don between Ardhuncart Lodge and the Mossat Burn confluence was highlighted as an issue of key concern to the landowner. Flooding is a natural river process influenced by the physical characteristics of a catchment, such as the topography and geology, as well as climate (both antecedent weather conditions and climatic change). These factors influence the hydrological response of the catchment to rainfall, with a faster response indicating a higher likelihood of flooding. However, this response can be further modified by changes to land management including increased land drainage, loss of catchment woodland and riparian vegetation, as well as channel alterations, for example straightening and construction of embankments, which cumulatively contribute towards an increased catchment response rate. The flooding experienced within the lower half of the Ardhuncart Estate is likely to be a culmination of these natural and anthropogenic factors.

This report presents a scoping-level assessment of potential restoration, NFM and habitat improvement options for Ardhuncart Estate. Several different intervention measures have been considered, with eleven site-specific Options Areas/work packages defined. These options provide a template for the implementation of nature-based restoration and management measures across the Estate. Each of the eleven work packages is designed to be taken forward as an individual project. However, it is important to note that the greatest benefits to ecology, geomorphology and flood risk can be achieved through the cumulative impact of multiple measures/work packages being implemented across the catchment. The ambition is that, as the benefits and potential of using the types of restoration measures presented here are increasingly appreciated, there will be a greater appetite to adopt catchment-scale measures.

NFM measures outlined within this report can be employed within the study site to deliver some degree of flood protection to the Estate and other settlements further downstream along the Don. However, for NFM to be truly effective and to increase resilience to future climate change, measures need to be implemented across a wider, catchment scale, addressing both the anthropogenic impacts of historic land management and channel modifications which have contributed to increase flood risk within the Don catchment. Therefore, a subsequent catchment-scale study is recommended to be carried out for the Upper Don, expanding upon this initial Estate-focused assessment.

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