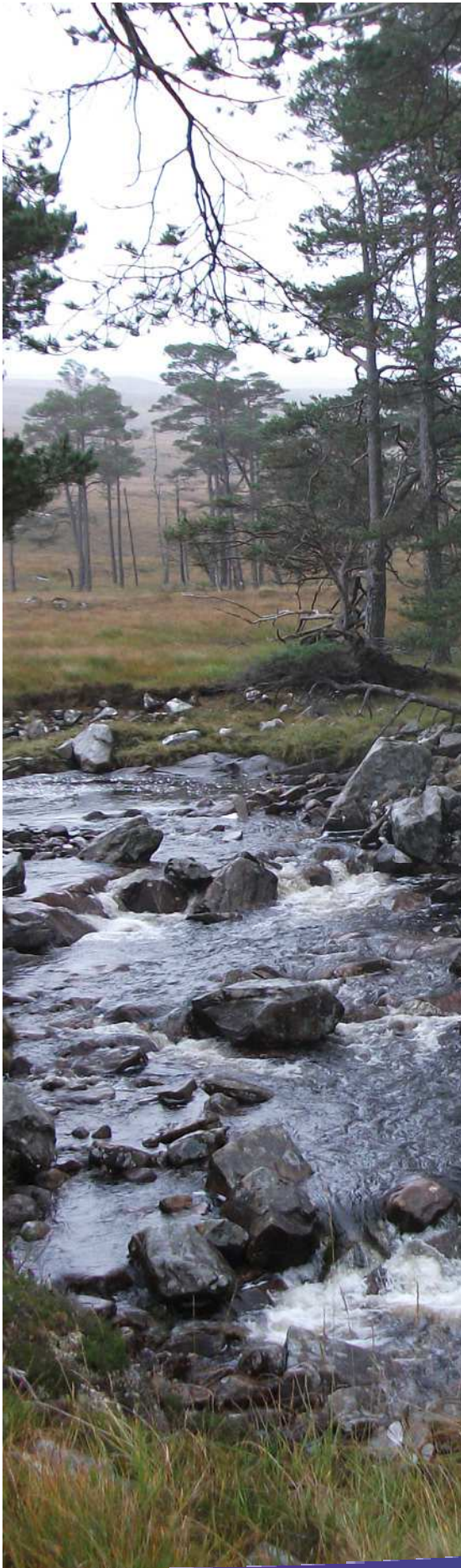




Galloway Glens Partnership

Natural Flood Management Scoping Study



06 December 2016

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1. Background

1.1. The River Dee Catchment

The River Dee is located in Dumfries and Galloway, south-west Scotland, and has a catchment covering an area of approximately 900 km² (Refer to Figure GB11820_M_001 in Appendix A). The River Dee catchment is comprised of predominantly of improved grassland, arable and broadleaved woodland within the lower lying areas. In the uplands, land cover ranges from extensive conifer woodland to acid and heather grasslands, with the highest of elevated areas being of montane habitat with isolated areas of bog.

The river rises in the upper reaches of the hills between Ayrshire and Galloway and follows a meandering valley form in a southerly direction passing the settlements of Carsphairn, New Galloway and Castle Douglas prior to reaching Kirkcudbright. The river network is often called the Dee-Ken system in reference to the significant contribution of the Ken tributary. The entire catchment forms part of the Galloway Hydro Scheme which was constructed in the 1930's. As a consequence, the hydro-scheme has considerably changed the functionality of the catchments and creation of a number of man-made lochs.

The catchment is heavily engineered and consists of six power stations, eight dams, and a network of tunnels, aqueducts and pipelines. The large storage capacity of the two main reservoirs, Loch Doon and Clatteringshaws, allows water to be stored in times of heavy rainfall and released later in a controlled fashion. It is acknowledged that without these water management features provided by the hydroelectric scheme the impact of flooding could be far greater. However, in extreme circumstances, or when rain falls persistently over a period of many weeks, floodwater can spill over dams or through floodgates and there is limited action that the hydroelectricity scheme can take to control flows and manage flooding.

Within the Dee catchment there are a number of settlements at risk of flooding from smaller tributaries of the Dee. The Dee catchment contains two Potentially Vulnerable Areas which were identified by SEPA during the National Flood Risk Assessment; *PVA 14/11 Castle Douglas* which includes Gelston, Castle Douglas, Crossmichael and Parton, and *PVA 14/22 Kirkcudbright* which includes Tongland and Kirkcudbright.

Other settlements within the catchment with a known risk of flooding but which are not contained within a PVA include New Galloway, St John's Town of Dalry, and Carsphairn. Carsphairn has been particularly affected, most recently from 'Storm Frank' in December 2015 which caused significant flooding impacting up to 30 properties in the village.

1.2. Scope of this study

The overall aim of this report is to undertake a scoping study in the River Dee catchment to assess the potential for using natural flood management techniques to reduce flood risk to downstream receptors and identify projects that could be undertaken through the delivery stage of the Galloway Glens Scheme. The project also aims to improve the status of the water bodies under the Water Framework Directive (WFD) and where applicable, provide additional benefits to biodiversity, recreation and amenity.

The project has been divided into various tasks as detailed in the following sub-sections. These initial stages are concerned with developing a detailed understanding of the geomorphic and hydrological processes operating within the River Dee system, the artificial impacts to physical processes and the natural flood regime.

1.2.1. Assessment of catchment characteristics

A detailed assessment of the catchment characteristics using a catchment wide desk-based GIS analysis of obtained datasets which are also supplemented by catchment reconnaissance surveys. The assessment focuses on the hydrological and geomorphological conditions but also accounts for environmental, social, infrastructure and land use issues.

1.2.2. Catchment restoration strategy

A detailed appraisal of the possible restoration options based in the findings of the above task that can be implemented to reduce flood risk and contribute to achieving the secondary aims and objectives.

1.2.3. Landowner and Stakeholder Engagement

Early dialogue with landowners and relevant stakeholders in the catchment restoration strategy to ensure their feedback can be incorporated into the strategy. Local knowledge, collective experience and overall support to the project will help to optimise the measures proposed.

Overall the objectives of the study are as follows:

- Compile existing spatial datasets to provide a catchment-scale dataset;
- Analyse the nature and distribution of these spatial datasets;
- Use hydrological modelling to identify potential locations for NFM within the River Dee catchment and quantify the potential reduction in flooding severity from undertaking NFM measures at these locations;
- Provide a series of prioritised restoration options across the River Dee that will help restore river bodies to good ecological status and also deliver a quantifiable reduction in downstream flood risk through NFM;

1.3. Legislation and Policy

1.3.1. The Flood Risk Management Act (Scotland) Act 2009

In Scotland, the framework for delivering a more sustainable approach to flood risk management has been implemented through the Flood Risk Management (Scotland) Act 2009 (the Act) transposed from the European Directive 2007/60/EC (the Flood Directive). This Act provides a framework to manage flood risk in a sustainable and co-ordinated method to scales on a local and national basis.

Following a perceptible increase in wet summers and wetter winters the duties of the Act and the responsibilities of SEPA, Scottish Water and local authorities to work together and integrate to manage flood risk where the benefits of intervention will have the greatest benefit.

Natural Flood Management (NFM) is one element of a sustainable approach to flood management and presents a set of measures which attempt to work with natural catchment processes to restore or improve the capacity of the landscape to store water, attenuate peak flows and direct flood waters to areas where it will cause the minimal amount of damage.

1.3.2. Scottish Planning Policy

The aim of Scottish Planning Policy (SPP), first published in 2010, is to ensure that flood risk is taken into account at all stages in the planning process and is given the due consideration it requires for it to be appropriately addressed.

The guiding principles of SPP aim to promote:

- A precautionary approach to flood risk from all sources, including coastal, watercourse (fluvial), surface water (pluvial), groundwater and any other sources. Consideration of the predicted effects of climate change should also be taken into account;
- Flood avoidance by safeguarding flood storage and conveying capacity, and situating development away from functional floodplains and medium to high risk areas;
- Flood reduction by assessing flood risk and, where appropriate, undertake natural and structural management measures, including flood protection, restoring natural features and characteristics, enhancing flood storage capacity, avoiding the construction of new culverts and opening existing culverts where possible; and
- Avoid increased surface water flooding through requirements for Sustainable Drainage Systems (SuDS) and minimising the area of impermeable surfaces.

Within the SPP, a risk framework approach identifies flood risk at three main categories:

1. **Little or no risk area** – annual probability of flooding less than 0.1% (i.e. one in 1000 year flood). No constraints to development due to flood risk.
2. **Low to medium risk area** – annual probability between 0.1% and 0.5% (i.e. between one in 1000 and 200 year floods). Usually suitable for most development.
3. **Medium to high risk area** – annual probability greater than 0.5% (i.e. one in 200 year flood). Generally not suitable for essential civil infrastructure such as hospitals, fire stations, emergency depots etc. The policy for development on functional floodplain applies. Land raising may be acceptable.

If built development is permitted, appropriate measures to manage the flood risk will be required and the loss of flood storage capacity mitigated to produce a neutral or better outcome.

Residential, institutional, commercial and industrial development within built-up areas may be acceptable if flood prevention measure to the appropriate standard already exist, are under construction or are planned as part of a long-term development strategy.

1.3.3. Controlled Activity Regulations

Under the Water Environment (Controlled Activities) (Scotland) Regulations 2011, any activity which may influence the water environment must be authorised, through obtaining an environmental licence. The Scottish Environment Protection Agency (SEPA) have jurisdiction for granting works that may affect the water environment, this includes the undertaking of engineering activities in or near water bodies and discharges to water and groundwater.

1.4. Flood Frequency

Within this study rainfall and flow are events are defined in terms of their recurrence interval (return period) which is an estimate of the likelihood of an event to occur. The return period is not a measure of how often or regularly an event will occur but is a measure of the risk of that event happening in any given year (Annual Exceedance Probability – AEP). For example the 100-year flood can be expressed as the 1% AEP flood, which has a 1% chance of being exceeded in any year.

2. Natural Flood Management

SEPA have produced guidance in the form of their “Natural Flood Management Handbook” that aims to provide a practical guide to the delivery of natural flood management to benefit flooding. The following sections outline the need, methods and outcomes that natural flood management can offer.

2.1. Overview of Natural Flood Management

With projected climate change expected to increase the frequency and severity of floods in the future there will be an increasing pressure on flood risk management to maintain current levels of flood protection as well as reducing future flood risk. Traditional approaches to flood management, such as direct defences in the form of hard engineered flood walls, are not considered sustainable. Therefore, a more holistic approach of managing land and water throughout the river catchment is required.

Natural flood management is based on this catchment wide approach and is typically aimed at measures that work with natural features and processes to slow and reduce flood water runoff. In addition to benefits to flooding, natural flood management approaches often contribute to improvements in biodiversity, water quality, and carbon storage. While it is recognised that natural flood management is unlikely to provide a total solution to flood risk on its own, it can be used alongside more traditional approaches to help reduce the height of flood defences and/or extend their life.

2.2. Aims of Natural Flood Management

Land management activities, such as the following, have had a significant impact on the hydrological process:

- Deforestation reduces the extent and intensity of precipitation that is intercepted resulting in higher levels of precipitation reaching the ground surface.
- Intensive agriculture practices (heavy machinery, drainage, etc) have reduced the ability of soils to hold and infiltrate water.
- Similarly, commercial forestry operations (drainage, up and down slope planting, etc) have reduced the ability of soils to hold and infiltrate water and increased runoff rates.
- Changes to natural river channels have increased the risk of flooding. Straightening river channels can result in increased volumes of flows which can exacerbate flooding downstream. Similarly, the creation of embankments can prevent water flooding into the natural floodplain, pushing this flow further downstream with increased flood risk in the downstream reaches.
- Overgrazing and livestock poaching of river banks, exposed soils (i.e. through crop planting and ploughing) and poor river engineering practices can result in excessive erosion and deposition of sediment which can reduce the flow conveyance capacity of rivers.

The combined long-term effect of the above activities has been to increase the volume and rate of surface runoff and reduce the ability of rivers and their floodplains to manage flood waters.

Natural flood management measures aim to redress these impacts by storing more water on the land and/or slowing the flow of water overland or instream. The desired effect of this on flooding is to:

- Reduce the downstream flood peak thus reducing the scale and impact of the flood; and/or
- Delay the arrival of the flood peak downstream, thus increasing the time available to prepare.

2.3. Other Benefits of Natural Flood Management

Like so many solutions that seek to utilise natural processes, it is considered when well designed and delivered effectively, NFM measures can provide additional benefits for both people and nature, including:

Biodiversity – many NFM measures (e.g. wetland, re-introduction of meanders, woodland creation) directly restore or strengthen an ecosystem which in turn supports a wider range of habitats and species.

Water quality and sediment management – restoration of the natural sediment processes can result in improved water quality through reduced sediment loads.

Channel morphology – natural flood management measures within the river channel or on its banks can improve instream ecology.

Climate change adaptation – many NFM measures can deliver more resilient ecosystems by increasing the capacity of the ecosystem to respond to disturbance and damage.

Carbon storage – floodplains, peatlands and woodlands all store carbon, removing carbon dioxide from the atmosphere.

Society and economy – environmental improvements can result in improved quality of life. Measures in public spaces or that create public spaces can also support many recreational activities such as walking, orienteering and mountain biking while at the same time improving health and mental well-being. These benefits can increase the availability of jobs.

Agricultural production – natural flood management measures that improve soil structure reduce the loss of valuable topsoil and can increase productivity.

2.4. Typical Natural Flood Management Measures

Within this study, NFM measures have generally been grouped within three typical NFM actions, namely:

River Reach and Floodplain Storage – measures that seek to enhance the mainstream and flood plain flood behaviour.

Runoff Reduction – measures that aim to minimise the runoff from the upstream catchments and reduce the volume and rate of flow entering the watercourses.

Sediment Management – measures that aim to increase the channel conveyance and/or reduce the problematic sediment loads that can reduce channel conveyance.

The typical NFM measures are outlined below. It should be noted that some NFM measures can be considered to sit within more than one of the NFM actions noted above.

2.4.1. River Reach and Floodplain Storage

Floodplain and Riparian Woodland

This measure involves planting woodland either in the floodplain or along the riparian corridor. The main hydrological benefits for woodland creation are considered as:

- Reduction in the volume of precipitation that reaches the ground (interception) by catching precipitation in the leaf canopy.
- Reduction in runoff by improving the infiltration rates of soils and soaking up water (evapotranspiration).
- Riparian woodland can stabilise river banks and help with sediment control.

Instream Structures

This measure involves the installation of porous dams within the river channel (typically using woody debris or boulders) that slow flow down. This results in an increase in water levels during medium to high flow events that increases the water storage within the channel and on the floodplain.

Washlands and Offline Storage Ponds

This involves the creation of areas adjacent to watercourses where flood water is directed to at times of high flow and temporarily stored until the flood peak has passed. This results in enhanced storage (attenuation) with a resultant reduction in the peak flow.

2.4.2. Runoff Reduction

Land and Soil Management Practices

These measures are land based techniques and soil practices that aim to reduce the amount of surface runoff that reaches the river networks. Measures can include:

- Planting cover crops so the soil surface is not left bare and exposed (reduce sediment runoff and reduce rate of runoff),
- Soil aeration and relieving compaction (increases infiltration by improving the ability of soil and subsurface to absorb water),
- Machinery practices that minimise compaction (prevent over compaction of soil to maintain its infiltration capacity),
- Runoff control features such as buffer strips and hedges.

Agricultural and Upland Drainage Modifications

These measures involve modifying existing drainage systems to benefit flooding by altering the flow pathways over and through the soil, as well as the hydrological connectivity to the drainage network. Measures can include:

- Upland drain blocking to encourage excess water to be redistributed back out onto the moorland surface.
- Lowland drain modifications to slow water and encourage settlement of sediment.
- In-field underdrainage interventions (breaking of field underdrains to create wetlands).

2.4.3. Sediment Management

Overland Sediment Traps

This involves the creation of containment areas where sediment laden runoff is detained to allow sediment to settle out of the runoff.

River Bank Restoration

This involves the restoration or protection of river banks suffering from unnaturally high levels of erosion. There are many techniques ranging from the installation of fencing to prevent livestock poaching the banks, allowing the river bank to re-vegetate and stabilise naturally to direct re-vegetation by planting.

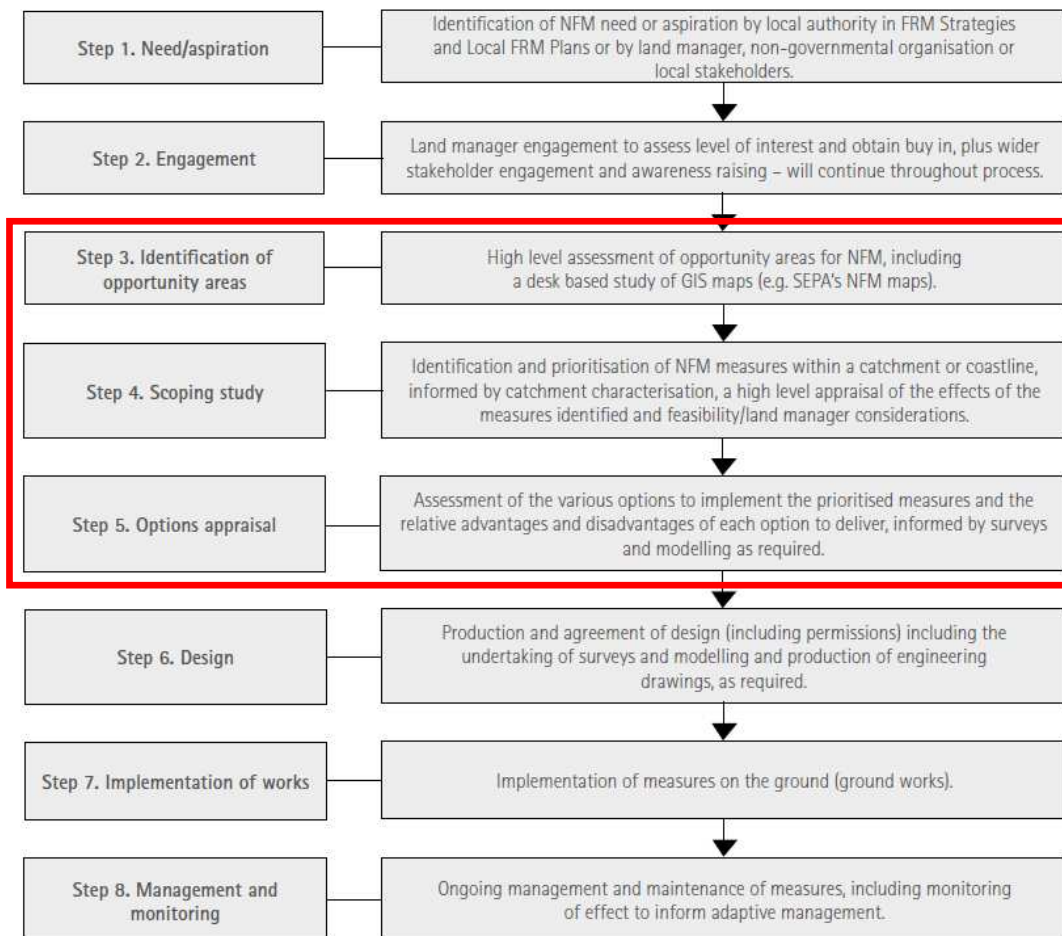
River Morphology and Floodplain Restoration

This involves the restoration of the channel morphology to increase the sinuosity of straightened channels and/or directly reconnect the floodplain through removal, breaching or lowering of embankments.

3. Natural Flood Management Approach

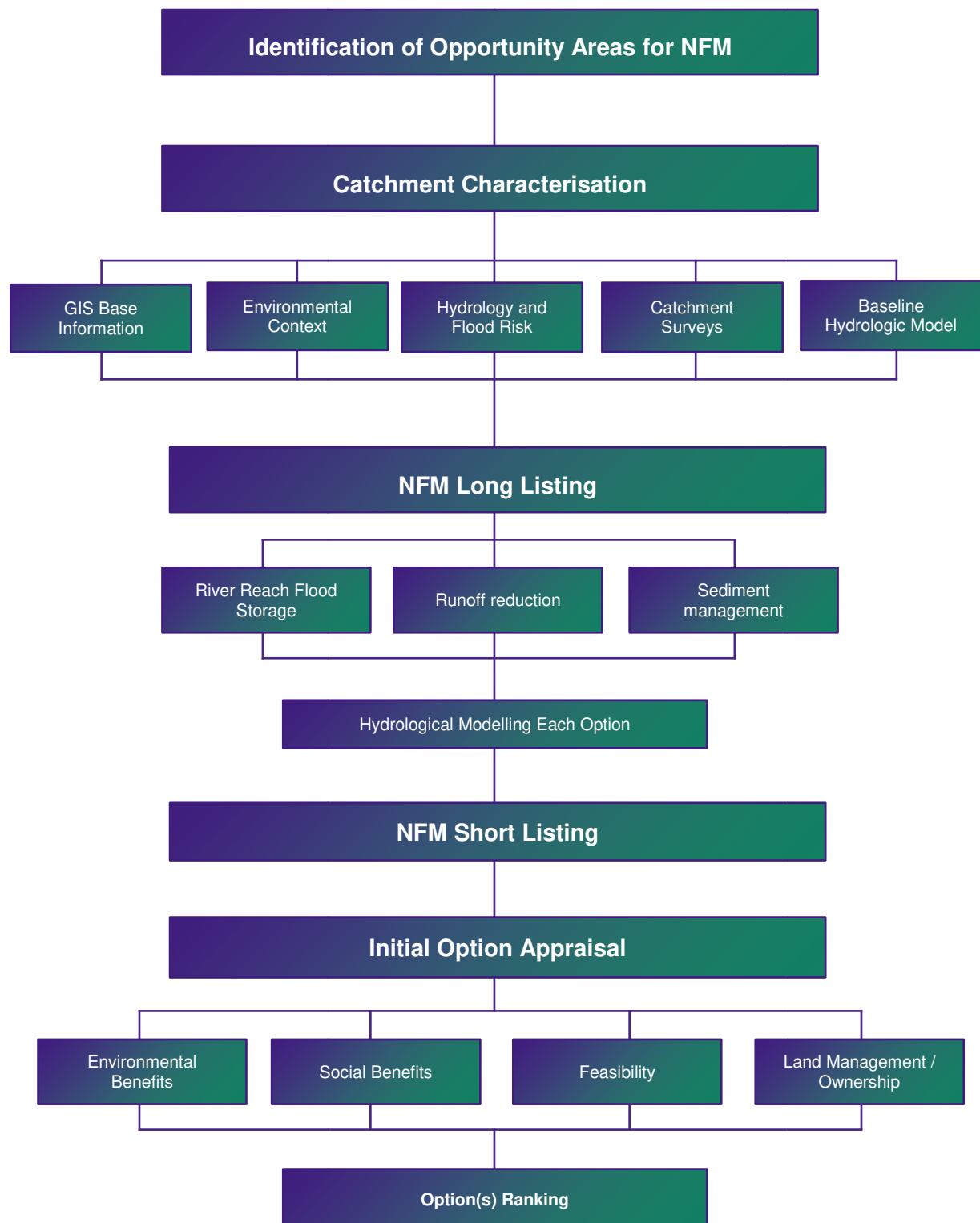
3.1. Overview of Approach

The overall process in developing a NFM approach are described in the SEPA NFM Handbook (see flow chart extract below) which has been used as the basis for this study. The steps within that which are addressed by this present study are highlighted.



3.2. Adopted Approach

The following flow chart illustrates the approach adopted by Natural Power for this study. Further details on each of the steps are provided in the relevant sections below.



3.2.1. Identification of Opportunity Areas for Natural Flood Management

The Galloway Glens Partnership are investigating the potential implementation of NFM measures within the River Dee catchment. Through their initial work with the community and local authority several areas within the River Dee catchment have been identified as offering potential for implementing NFM measures.

Natural Power have built on this initial work by Galloway Glens Partnership to review and assess these areas for suitability of NFM measures.

3.2.2. Catchment Characterisation

Using existing spatial data sets within GIS and information from SEPA's baseline studies an initial assessment of the study area characteristics has been undertaken. This provided a solid baseline of information on the catchment and how it responds to flooding events that has informed the development of NFM options.

The catchment characterisation stage included the following key assessments:

- Environmental context (topography, precipitation, soil type, land cover and land use, WFD status);
- Hydrology and flood risk (response of the catchment to flood flows, analysis of median annual maximum flow and time to peak);
- Catchment surveys (ground truth desktop data and inspection of NFM opportunity areas)
- Baseline hydrological model (creation of a catchment scale hydrological model).

From the above assessments, catchment maps were produced that aided the identification of NFM measures and opportunities to deliver additional benefits.

3.2.3. NFM Long Listing

Having developed a solid baseline of the catchment details, a long list of possible NFM options has been identified. NFM measures have been considered based around the following three actions:

- River and Floodplain Restoration (enhancing the mainstream and flood plain flood behaviour).
- Runoff Reduction (minimising runoff from the upstream catchments).
- Sediment Management (seeking opportunities for increase conveyance).

3.2.4. NFM Short Listing

Each of the long list options was assessed in the catchment scale hydrological model to simulate the potential effect on flood risk. This has enabled quantification of the percentage change in flood flows a NFM measure would have compared to the baseline.

Where long list NFM measures have a sufficient impact on flood risk, they have then been progressed to the short list.

3.2.5. Initial Option Appraisal

The initial option appraisal stage identified and reviewed the short list option(s) to implement the prioritised measure(s) and their relative advantage(s) and disadvantage(s).

The main objective of this stage is to provide sufficient information to enable agreement to be reached on the preferred option(s), in consultation with the landowner/land manager and other stakeholders, and to outline additional assessments/surveys required to progress the preferred option(s).

The option appraisal stage has assessed the following criteria for the short listed option(s):

- Feasibility / Engineering,
- Land Management,
- Hydrological,

- Environmental (flora and fauna, water, soil, etc),
- Social.
- Landscape Impact

From this initial option appraisal the short list option(s) have been ranked to provide a list of prioritised measures that Galloway Glens Partnership can take forward for detailed consultation with landowners.

4. Identification of Opportunity Areas

The River Dee was heavily engineered, including large reservoirs, to create the Galloway Hydro Scheme. Although this may limit the opportunity areas for NFM measures, there are a number of settlements at risk of flooding from smaller tributaries of the River Dee.

The River Dee catchment contains two Potentially Vulnerable Areas (PVAs) which were identified by SEPA during the National Flood Risk Assessment. PVA 14/11 Castle Douglas, includes Gelston, Castle Douglas, Crossmichael and Parton, and PVA 14/22 Kirkcudbright, includes Tongland and Kirkcudbright. Other settlements within the River Dee catchment with a known flood risk include New Galloway, St John's Town of Dalry and Carsphairn.

4.1. SEPA NFM Maps

SEPA prepared natural flood management maps as a requirement of Section 20 of the Flood Risk Management (Scotland) Act 2009. These maps were the result of work undertaken by SEPA to consider whether techniques that work with natural features and characteristics can contribute to managing flood risk. The natural flood management maps are a source of information on areas where natural flood management would be most effective within Scotland. It should be noted that they are strategic high level maps and should be used as guidance only.

There are three maps of relevance to this study that consider the NFM actions (as outlined in Section 3.2.3), namely:

- Floodplain Storage,
- Runoff Reduction,
- Sediment Management.

4.2. Galloway Glens Partnership NFM Areas

Galloway Glens Partnership initial work on the project with the local communities within the River Dee catchment and Dumfries & Galloway Council, identified potential areas that may be suitable for locating NFM measures. These included the following areas:

- The catchment to the west of New Galloway on the Damcroft Burn,
- The River Dee floodplain from St John's Town of Dalry through to New Galloway,
- The catchment to the north and north west of Carsphairn on the Water of Deugh, Carsphairn Lane and Garryhorn Burn,
- The catchment upstream of Clatteringshaws Loch,
- The catchments of the Black Water of Dee, including Loch Grannoch.

4.3. NFM Opportunity Areas

Natural Power undertook a review of the above areas to identify and verify the areas considered most suitable for implementation of NFM measures. Figure GB11820_M_011 in Appendix B outlines the areas that have formed the focus of this study.

4.3.1. Identified Receptors

Within the opportunity areas, the following key receptors were identified:

- Carsphairn,
- Dalry Floodplain,
- New Galloway,
- Clatteringshaws Loch,
- Castle Douglas,
- Kirkcudbright.

4.3.2. Importance of Receptors

The importance of these receptors was assigned based on their historic flood risk, number of properties at risk of flooding and their regional significance.

Carsphairn in a regional context is a very small settlement but has experienced significant flooding and has been identified as being at risk to flooding in frequent events. Hence, it is considered of high importance.

Dalry Floodplain and New Galloway in a regional context are small settlements and are understood to be at a lesser flood risk. Therefore, these are considered to be of medium importance.

Clatteringshaws Loch is not a settlement as such but has significant importance in terms of the Galloway Hydro Schemes and is therefore considered to be of medium importance.

Castle Douglas and Kirkcudbright, in a regional context, are large settlements with a known history of flooding. They are identified within Potential Vulnerable Areas (PVA's) 14/11 and 14/22. Therefore, they are considered to be of very high importance.

The table below summarises the importance of the identified receptors.

Table 4.1: Importance of Receptors

Receptor	Importance
Carsphairn	High
Dalry Floodplain	Medium
New Galloway	Medium
Clatteringshaws Loch	Medium
Castle Douglas	Very High
Kirkcudbright	Very High

5. Catchment Characterisation

The information presented in the following sections presents the results of the catchment characterisation, which included the completion of desktop study and high level site reconnaissance survey.

5.1. Environmental Context

5.1.1. Catchment Situation

The River Dee is a main river in south-west Scotland, which rises in the hills around the Rhinns of Kells to the west and Cairnsmore of Carsphairn to the north and generally flows from north to south and drains approximately 900 km². At its most southern extent the River Dee joins the tidally influenced reach at Tongland Bridge, north of Kirkcudbright, Dumfries and Galloway. As shown in Figure GB11820_M_002 (Appendix A), the catchment rises to a maximum altitude of 814 m above ordnance datum (AOD) at the Corserine in the west of the catchment with other highs of over 700 mAOD at Cairnsmore of Carsphairn to the north.

Figure GB11820_M_003 (Appendix A) provides an indication in the variation of ground surface slopes across the catchment that suggests a mean slope of 7.75 m/m across the entire catchment. This compares with the FEH Mean Drainage Path Slope (DPSBAR) of 117.6 m/km which is more heavily influenced by the slope of the main River Dee.

5.1.2. Development

5.1.3. Precipitation

The FEH Standard Average Annual Rainfall (SAAR) for the catchment is 1709 mm. To put this into context, rainfall in Scotland varies from under 800 mm a year on mainland eastern Scotland in areas such as Fife to over 3000 mm on the mainland Western Highlands.

5.1.4. Soil Types

The Soil Classification and Hydrology of Soil Types (HOST) are shown in Figures GB11820_M_008 and GB11820_M_006 (Appendix A), respectively. Within the River Dee catchment it can be seen that the low-lying areas of the catchment are predominantly mineral soils with negligible to moderate storage capacity that are underlain by rocks with no to negligible storage capacity (HOST class 17, 19 & 24). The soils data also indicates that the upland areas of the catchment are dominated by peats, podzols and groundwater gleys with HOST classes of 15 and 29, respectively. The HOST classes indicate that the upland areas of the catchment are permanently wet, peaty topped upland soils and/or peat. The storage capacity of the underlying substrate also varies from relatively free draining to having no storage capacity.

Figure GB11820_M_018 (Appendix A) also provides details on the SNH carbon soils, deep peat and priority peatland habitat mapping. Following consultation, SNH have provided five classes of carbon and peatland soils, based on combining soil type and habitat cover.

As presented in Figure GB11820_M_018:

- Class 0 makes up the majority of the low lying areas of the catchment which corresponds with the presence of mineral soils
- Classes 1, 2, 3 & 4 make up the open areas within the upland areas of the catchment.
 - Classes 1 & 2 are considered a nationally important resource and described as soils that are carbon-rich deep peat with vegetation that is entirely or at least dominated by priority peatland habitats. Deep peat corresponds to peat soil mapping units characterised by the presence of surface peat layers containing more than 60% organic matter and at least 50 cm thick.
 - Classes 3 & 4 are the most dominant and are described as soils where the vegetation is not dominated or unlikely to be associated with priority peatland habitat.

- Class 5 make up a significant coverage of the upland areas. This is described as soils where peatland habitat is recorded but all soils are described as carbon rich and deep peat. These soils are consistent with areas dominated by commercial forestry.

5.1.5. Land Cover

The Land Capability Map 2000 data (LCM), as shown in Figure GB11820_M_004, has identified seventeen land cover types across the catchment. The predominance of improved grassland (4), arable and horticulture (3) and broadleaved woodland (1) within the more low lying areas of the catchment concurs with the predominance of brown forest mineral soils. In the upland areas, which are underlain by wet peat/peaty soils, the dominant land cover ranges from coniferous woodland (2), acid grassland (8) and heather grassland (11). The areas with the highest elevation are identified as being montane habitat and there are isolated areas of bog (12).

Table 5.1 presents the area (km²) of the varying types of land cover within the catchment.

Table 5.1: Area of varying landcover types

Classification	LCM2007 code	Area (km ²)	% of Total Catchment Area
Broadleaved Woodland	1	31.52	3.51
Coniferous Woodland	2	298.62	33.25
Arable and Horticulture	3	24.28	2.70
Improved Grassland	4	135.73	15.11
Rough Grassland	5	58.76	6.54
Acid Grassland	8	163.16	18.17
Fen, Marsh and Swamp	9	0.25	0.03
Heather	10	9.98	1.11
Heather Grassland	11	108.78	12.11
Bog	12	31.51	3.51
Montane Habitat	13	11.57	1.29
Inland Rock	14	0.98	0.11
Saltwater	15	0.021	0.002
Freshwater	16	19.7	2.19
Littoral Sediment	20	0.002	0.0002
Urban	22	0.91	0.10
Suburban	23	2.43	0.27

Source: LCM2007 & Natural Power

5.1.6. Designated Sites

The designated sites within the catchment are shown in Figures GB11820_M_005 and GB11820_M_017 (Appendix A) are as summarised below in the following paragraphs.

Special Areas of Conservation

The Merrick Kells Special Area of Conservation (SAC) is the only such designated to be located within the catchment. The qualifying features of the SAC are:

- Acid peat-stained lakes and ponds;
- Acidic scree;
- Blanket bog;

- Clear-water lochs with aquatic vegetation and poor to moderate nutrient levels;
- Depressions on peat substrates;
- Dry heaths;
- Montaine acid grasslands;
- Otter;
- Plants in crevices on acid rocks; and
- Wet heathland with cross-leaved heath.

Special Protection Area

The Loch Ken and River Dee Marshes Special Protection Area (SPA) is located within the catchment and is designated as an international important roost for both Greenland white-fronted goose and Greylag goose.

Sites of Special Scientific Interest

There are fourteen Sites of Special Scientific Interest (SSSI) within the River Dee catchment:

4. Airds of Kells Wood;
5. Cairnbaber;
6. Cairnsmore of Fleet;
7. Clatteringshaws Dam Quarry;
8. Cleugh;
9. Ellergower Moss;
10. Hannaston Wood;
11. Kenmure Holms;
12. Laughenghie and Airie Hills;
13. Merrick Kells;
14. River Dee (Parton to Crossmichael);
15. Threave and Carlingwalk Loch;
16. Water of Ken Woods; and
17. Woodhall Loch.

Scheduled Ancient Monuments and Listed Buildings

There are 194 designated cultural heritage assets in the catchment. Their names can be provided on request if required.

Gardens and Designated Landscapes

Threave Gardens is the only garden and designated landscape in the catchment. It is noted there are also a number of non- inventory gardens and landscapes.

5.1.7. Water Framework Status

The existing and historic water quality status of the River Dee catchment and its tributaries is summarised in Table 5.2 and shown in Figure GB11820_M_009 (Appendix A). Within Table 5.2 is a timescale, under the objectives of the River Basin Management Plan, in which achieving a status of 'good' can be met. The 2015 status of the waterbodies has been based on the data provided on the Scotland's Environment interactive web mapper.

The pressures to achieve an overall good status are consistent the man-made influences in the catchment. This includes hydromorphological modifications, acid rain, barriers to fish migration, abstractions and diversion of water required for hydroelectricity generation, as well as the introduction of alien invasive species (North-American crayfish)

Table 5.2: SEPA RBMP Waterbody Classification

ID	Waterbody Name	Historic and Current Overall Classifications					Predicted Future Overall Classifications		
		2011	2012	2013	2014	2015	2021	2027	Long Term
10545	River Dee (Loch Ken Outlet to Tongland)	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
10546	Black Water of Dee (Pullaugh Burn to Loch Ken)	Bad	Bad	Moderate	Moderate	Poor	Moderate	Moderate	Good
10547	Black Water of Dee (Loch Dee to Clatteringshaws Reservoir)	Poor	Poor	Poor	Poor	Poor	Poor	Moderate	Good
10548	Dargall Lane	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Good
10549	Cooran Lane/March Burn	Poor	Poor	Poor	Poor	Poor	Poor	Good	Good
10550	Garray Burn/Minnigall Lane	Poor	Poor	Poor	Poor	Poor	Poor	Good	Good
10551	Pullaugh Burn	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Good
10552	Cuttiemore Burn	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Good
10553	Airie Burn	Poor	Poor	Poor	Poor	Poor	Good	Good	Good
10554	Crae Lane (d/s Woodhall Loch)	Good	Good	Good	Good	Good	Good	Good	Good
10555	Camelon Lane (u/s Woodhall Loch)	Moderate	Good	Good	Good	Good	Good	Good	Good
10556	Shirmers Burn	Moderate	Moderate	Poor	Poor	Poor	Good	Good	Good
10558	Water of Ken (d/s Kendoon)	Bad	Bad	Bad	Bad	Bad	Bad	Good	Good
10559	Water of Ken (u/s High Bridge of Ken)	Moderate	Moderate	Moderate	Poor	Poor	Poor	Good	Good
10560	Poliferie Burn	Moderate	Moderate	Moderate	Poor	Poor	Poor	Good	Good
10561	Stroanfreggan Burn	Moderate	Moderate	Moderate	Poor	Poor	Poor	Good	Good
10562	Water of Deugh (Carsphairn Lane to Water of Ken)	Poor	Poor	Poor	Poor	Poor	Poor	Good	Good
10563	Water of Deugh (u/s Carsphairn Lane)	Bad	Bad	Poor	Poor	Poor	Poor	Good	Good
10564	Pochriegavin Burn	Moderate	Moderate	Poor	Poor	Poor	Poor	Good	Good
10565	Bow Burn	Bad	Bad	Moderate	Poor	Poor	Poor	Good	Good
10566	Carsphairn Lane	Moderate	Moderate	Moderate	Poor	Poor	Poor	Good	Good
10567	Garryhorn Burn	Moderate	Moderate	Moderate	Poor	Poor	Poor	Good	Good
10568	Polmaddy Burn	Bad	Bad	Bad	Bad	Bad	Bad	Good	Good
10569	Polharrow Burn/Mid Burn/Hawse Burn	Bad	Bad	Poor	Poor	Poor	Poor	Good	Good
10570	Coom Burn / Garroch Burn	Good	Good	Good	Good	Moderate	Good	Good	Good
10571	Knocknairling Burn	Good	Good	Good	Good	Moderate	Good	Good	Good
10572	Garple Burn/Margree Burn	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
10573	Black Water	Moderate	Moderate	Moderate	Poor	Poor	Poor	Good	Good

ID	Waterbody Name	Historic and Current Overall Classifications					Predicted Future Overall Classifications		
		2011	2012	2013	2014	2015	2021	2027	Long Term
10574	Black Bridge Burn	Moderate	Moderate	Moderate	Good	Good	Good	Good	Good
10575	Gelston Burn/Carlingwark Lane	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Good	Good
10576	Auchlane Burn	Moderate	Good	Good	Good	Good	Good	Good	Good
10722	Black Water of Dee (Clatteringshaws Reservoir to Pullaugh Burn)	Bad	Bad	Bad	Bad	Poor	Bad	Moderate	Good
10761	Water of Ken	Bad	Bad	Bad	Bad	Bad	Bad	Moderate	Moderate

Source: SEPA and Scotland's Environment

Figure GB11820_M_007 (Appendix A) also presents the morphological pressures for each of the WFD waterbodies, with a summary of these presented in Table 5.3.

Table 5.3: Morphological Pressures

Morphological Pressures												
ID	Waterbody Name	Impoundments	Bridges	Boatslips	Fords	Intakes and Outfalls	Pipe Cable Crossings	Embankments (No reinforcement)	Hard bank reinforcement	Green bank reinforcement	Set back embankment	Partial realignment
10545	River Dee (Loch Ken Outlet to Tongland)	3	7	1	0	5	1	5 (3,214 m)	5 (493 m)	2 (50 m)	6 (982 m)	0
10546	Black Water of Dee (Pullaugh Burn to Loch Ken)	0	3	1	1	0	0	3 (286 m)	1 (69 m)	0	4 (676 m)	0
10547	Black Water of Dee (Loch Dee to Clatteringshaws Reservoir)	0	3	0	0	0	0	0	0	0	0	0
10548	Dargall Lane	1	0	0	0	0	0	0	0	0	0	0
10549	Cooran Lane/March Burn	0	1	0	0	0	0	0	0	0	0	0
10550	Garrary Burn/Minnigall Lane	1	1	0	0	0	0	0	0	0	0	0
10551	Pullaugh Burn	1	1	0	0	0	0	0	0	0	0	0
10552	Cuttiemore Burn	0	1	0	0	0	0	0	0	0	0	0
10553	Airie Burn	0	2	0	0	0	0	0	0	0	0	1 (665 m)
10554	Crae Lane (d/s Woodhall Loch)	0	1	0	0	0	0	0	0	0	0	0
10555	Camelon Lane (u/s Woodhall Loch)	0	3	0	0	0	0	0	0	0	0	2 (3,690 m)
10556	Shirmers Burn	0	5	0	0	0	0	0	0	0	0	0
10558	Water of Ken (d/s Kendoon)	3	2	0	0	0	0	0	0	1 (205 m)	2 (861 m)	0
10559	Water of Ken (u/s High Bridge of Ken)	0	5	0	1	0	0	0	0	0	0	0
10560	Poliferie Burn	0	2	0	0	0	0	0	0	0	0	0
10561	Stroanfreggan Burn	0	2	0	0	0	0	0	0	0	0	1 (604 m)
10562	Water of Deugh (Carsphairn Lane to Water of Ken)	0	2	0	0	1	0	0	1 (226 m)	1 (19 m)	2 (227 m)	0
10563	Water of Deugh (u/s Carsphairn Lane)	1	8	0	2	0	0	0	1 (87 m)	0	0	0
10564	Pochriegavin Burn	0	0	0	0	0	0	0	0	0	0	0
10565	Bow Burn	1	2	0	0	0	0	0	0	0	0	0
10566	Carsphairn Lane	2	4	0	1	0	2	0	0	0	0	0
10567	Garryhorn Burn	0	2	0	1	0	0	0	0	0	0	0
10568	Polmaddy Burn	0	3	0	2	0	0	0	0	0	0	0
10569	Polharrow Burn/Mid Burn/Hawse Burn	0	10	0	2	0	0	0	0	0	0	0
10570	Coom Burn / Garroch Burn	0	5	0	1	0	0	2 (852 m)	0	1 (26 m)	1 (739 m)	1 (701 m)

ID	Waterbody Name	Morphological Pressures										
		Impoundments	Bridges	Boatslips	Fords	Intakes and Outfalls	Pipe Cable Crossings	Embankments (No reinforcement)	Hard bank reinforcement	Green bank reinforcement	Set back embankment	Partial realignment
								m)		m)	m)	m)
10571	Knocknairling Burn	0	4	0	0	0	0	0	0	0	0	1 (418 m)
10572	Garple Burn/Margree Burn	1	5	0	2	0	0	0	0	0	0	0
10573	Black Water	1	2	0	0	0	0	0	1 (40 m)	0	0	1 (258 m)
10574	Black Bridge Burn	0	7	0	0	0	0	0	0	0	1 (689 m)	3 (5552 m)
10575	Gelston Burn/Carlingwark Lane	0	11	0	0	1	0	3 (915 m)	0	0	1 (122 m)	4 (5967 m)
10576	Auchlane Burn	0	6	0	0	0	0	0	0	0	0	4 (2814 m)
10722	Black Water of Dee (Clatteringshaws Reservoir to Pullaugh Burn)	1	2	0	0	0	0	0	0	0	0	0
10761	Water of Ken	1	3	0	1	3	0	13 (7267 m)	0	6 (388 m)	8 (3421 m)	0

5.1.8. Fisheries

The River Dee is native to a number of species such as Atlantic Salmon, Brown Trout and Pike and is classified as Salmonid Water under the Freshwater for Fish Directive (78/658/EEC). The Galloway Fisheries Trust (GFT) prepared a series of Fisheries Management Plans (FMP) across all catchments within Dumfries and Galloway aimed at providing plans for the management of fish and fishing within each of the catchments between 2009 and 2013. The plans consider effective remediation and improvement measures which will bolster and/or sustain the native fish stocks as well as ensuring that associated habitats are conserved and enhanced. Within the Technical FMP for Kirkcudbrightshire Dee the most significant factors which are restricting fish production and fishery performance in order of importance are as follows:

- Barriers of fish movement;
- Alien non-native species;
- Reduced flow;
- Acidification;
- Exploitation;
- Degraded instream habitat;
- Reduced survival at sea;
- Predation;
- Degraded riparian habitat;
- Pollution; and
- Parasites and disease.

Across the Kircudbrightshire Dee there exists a number of artificial barriers which can act as barriers to movement. Engineering structures such as dams, weirs and culverts may restrict the migration of fish species which is essential for particular species at spawning time. Natural waterfalls tend to be present in the headwaters of some tributaries but these can be outside of the areas which are used by migratory fish for spawning.

5.2. Site Reconnaissance Surveys

During the completion of the catchment characterisation a site survey was undertaken across the catchment. This survey was used to provide an overview of the environmental setting of the catchment, verify the GIS datasets and inform the hydrological modelling. Photographs 5.1 – 5.7 providing an overview of the key observations.



Photograph 5.1: Ground conditions and varying landcover with the Carsphairn Lane catchment



Photograph 5.2: Flood barrier under construction at Carsphairn



Photograph 5.3: Example of forestry drainage



Photograph 5.4: Clatteringshaws Reservoir Dam (note the varying land cover in the background of the picture)



Photograph 5.5: Broad, flat floodplain at Carsphairn



Photograph 5.6: Hydromorphological conditions of unnamed tributary of the Mill Burn (New Galloway)



Photograph 5.7: Hydromorphological conditions of upland watercourse (Pullhaugh Burn)

5.3. Hydrology and flood risk

5.3.1. Hydrometric data

According to the National River Flow Archives there is one flow gauging station operated by SEPA on the River Dee at Glenlochar as shown in Table 5.4.

Table 5.4: Summary of the flow gauging stations within the catchment

Gauge	Record Length	Catchment Area (km ²)	Median Annual Flood ¹ (m ³ /s)
Dee at Glenlochar (80002)	1977 – present	810	276.21

Source: National River Flow Archives, www.nrfa.ceh.ac.uk

Notes: 1 – Median Annual Flood calculated by catchment descriptors methodology (Kjeldsen et al. 2008)

The station at Glenlochar is a velocity-area monitoring location situated approximately 500 m downstream of the Glenlochar Barrage. This is the lowest station on the heavily regulated river, dominated by hydroelectric works. The gauging section consists of a gravel bed which contains some large boulders.

5.3.2. Hydrological assessment

The median annual maximum flow (Q_{med}) was estimated for each of the key catchments within the River Dee using the revised Q_{med} by catchment descriptors method. The results are shown below in Table 5.5 and Figure GB11820_M_019 (Appendix A).

Table 5.5: Summary of findings of Q_{med} for key locations within the River Dee catchment

Catchment	Area (km ²)	Median Annual Flood (m ³ /s)
Carsphairn	128.63	138.37
Water of Ken	88.23	85.15
Polharrow Burn	41.50	40.72
Loch Ken Inlet	472.27	271.52
Shirmers Burn	41.14	32.96
Clatteringshaws Loch Outlet	123.26	61.89
Black Water of Dee	229.23	107.93
Loch Ken Outlet	813.69	278.01
Carlingwark Lane Canal	25.90	11.69
River Dee at Tongland	899.66	293.51

5.3.3. Flood mapping

The SEPA derived flood maps within the catchment have been reviewed as part of this study.

SEPA's Indicative Flood Map (<http://www.sepa.org.uk/environment/water/flooding/flood-maps/>) provides predictive guidance on the possible extent of functional floodplains for catchments greater than 3 km². Fluvial flooding (1 in 200 year flood extent) associated with the River Dee is identified on the SEPA Indicative Flood Map. Significant stretches of the River Dee have been identified as being at High to Low risk of flooding, with categories defined below.

1. **Low risk** – annual probability of flooding less than 0.1% (i.e. one in 1000 year flood);
2. **Medium risk** – annual probability of flooding at 0.5% (i.e. one in 200 year flood); and

3. **High risk** – annual probability of flooding of 10% (i.e. one in 10 year flood).

The flood map shows that the areas of greatest risk of fluvial flooding are located within the bounds of the floodplain. For example, broad floodplains, such as the one at Carsphairn show the greatest extent of flooding. Upland watercourses that are located within incised valleys, show the smallest extent of flooding as the flows will be constrained by the hydromorphological conditions of the river.

However, the flood map has primarily been developed for strategic national overview purposes in Scotland, and does not provide sufficient detail to accurately estimate the flood risk associated with individual properties or specific point locations. Catchment Scale Hydrological Model

A numerical model of the Dee catchment was created using the HEC-HMS software package to enable simulation of the potential effects of the various NFM measures on flood flows. The model covers the entire River Dee catchment from its headwaters of the Water of Deugh and Water of Ken in the north to the outlet of Tongland Loch just upstream of Kirkcudbright in the south.

The Hydrologic Modelling System (HEC-HMS) software package has been developed by the US Army Corp of Engineers and is designed to simulate the complete hydrologic processes of dendritic watershed systems. The software allows a GIS-based approach to model development and visualising outputs.

5.3.4. **Baseline Model Development**

Development of GIS Data for Hydrological Model

HEC-GeoHMS is a Geographical Information System (GIS) extension that provides a set of procedures, tools and utilities for the preparation of data for import into HEC-HMS and generation of data for HMS output.

HEC-GeoHMS uses ArcGIS and the Spatial Analyst extension to develop a hydrologic modelling inputs for, HEC-HMS. Analyzing digital terrain data, HEC-GeoHMS allowed drainage paths and watershed boundaries to be transformed into a hydrologic data structure that represents the drainage network. The software also allowed the visualisation of spatial information, including watershed characteristics as well as performing spatial analysis to delineate sub-basins and streams.

Physical Representation of the Catchment

Using the GIS data a dendritic model of the whole catchment was created. This was made up of sub-catchments feeding into river reaches throughout the entire catchment to the outfall at Tongland Reservoir just upstream of Kirkcudbright. Figure 5.8 below and Figure GB11820_M_020 illustrate the overall model extents.

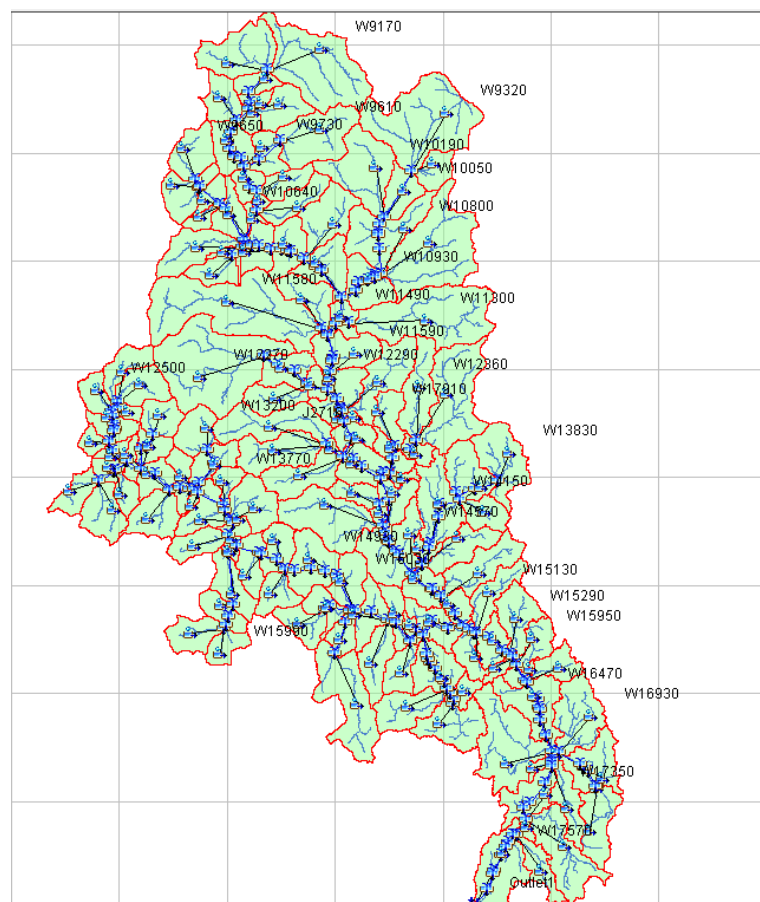


Figure 5.8: HEC-HMS Model Overview

Sub-Catchments

Each sub-catchment has been modelled based on physical data (e.g. area, drainage length, slope, etc) obtained using GIS analysis of topographic data.

The following methods were adopted for each sub-catchment in order to model the hydrological process which result in runoff, with the data inputs either added to the model or ascertained from the GIS data:

- **Canopy Method:** This method is used to simulate the effects of plants and vegetation on the sub-catchment. It enables evaporation of rainfall/water from the canopy, interception of rainfall due to the canopy and transpiration of water from the soil by the plants and vegetation.

Based on the LCM land cover classification initial parameters for each sub-catchment were selected to replicate the land cover. As noted in Section 5.1.5, the predominant landcover within the River Dee catchment is coniferous woodland.

- **Surface Method:** The surface method is used to represent the ground surface of a sub-catchment and enables features such as surface depressions where rainfall can accumulate prior to runoff to the river network.

Initial parameters for surface method for each sub-catchment were selected based on the terrain data and LCM land cover classification.

- **Loss Method:** The Loss Method is used to simulate infiltration into the soil structure.

The Hydrology of Soil Types (HOST) dataset defines 29 soil classes by their hydrological properties, particularly their ability to transmit water both vertically and horizontally. The HOST data enables an estimate of the standard percentage runoff (SPR) to be made.

Based on the HOST data for each sub-catchment, the corresponding SPR was estimated and used to define the Loss Method parameters (i.e. initial loss rate and constant loss rate) in the model for each sub-catchment.

- **Transform Method:** The transform method is used to simulate surface runoff for a catchment and is based on the unit hydrograph approach.
- **Baseflow Method:** This method simulates the baseflow in each sub-catchment. The initial baseflow parameters for the model were selected using the results of the FEH analysis of the catchment.

River and Reservoir Network

Each sub-catchment feeds into the river network covering the entire catchment. The Muskingum Cunge method was used to route the flows along the river reaches.

The length, slope and profile of individual river reaches were determined from the GIS data.

Rainfall Data

The design precipitation events were selected through utilisation of the Flood Estimation Handbook's Depth Duration Frequency (DDF) 1999 model with their outputs calculated using ReFH2 software. The input parameters for the DDF model are the characteristics extracted from each of the identified areas to provide point rainfall depths for each catchment.

In order to determine the final design rainfall depths, for each event duration, the point rainfall depth is multiplied by an areal reduction factor and a seasonal correction factor. By default, the 75% Winter Rainfall Profile was used as a representative hyetograph for the catchment.

The 1:2, 1:10, 1:50 and 1:200 rainfall data for durations from 2 hours to 22 hours were included within the model.

Calibration

A high level calibration of the HEC-HMS model was undertaken using flow estimates generated by ReFH2 which utilises the FEH catchment descriptors.

Using the design rainfall hyetographs outlined above, the modelled flows are generated using the revitalised rainfall-runoff model in ReFH2 under a range of return periods for the various event duration scenarios.

Based on the FEH methods flow hydrographs were generated for 'calibration points' which included significant catchments feeding into the River Dee as well as distinct points along the River Dee.

The following key model parameters were adjusted within the HEC-HMS model to calibrate the model output hydrographs to the hydrographs generated using FEH at these calibration points:

Table 5.6: Key Model Calibration Parameters

Hydrological Method	Parameter
Canopy	Initial Storage
Surface	Initial Storage
Loss	Initial
	Constant
Transform	Time of Concentration
	Storage Coefficient
Routing	Manning's n

Given the size of the model and the number of sub-catchments within it, the initial calibration focused on a single sub-catchment in the headwater of the Dee catchment. The above parameters were adjusted until a satisfactory comparison to the FEH hydrograph was achieved.

The parameters adjustments made to the above single sub-catchment were then applied to all sub-catchments within the model. Where required, further refinements were made to the parameters for sub-catchments contributing to a calibration point. On average the further refinements to the parameters were found to be within 11% of the single sub-catchment adjustments.

Calibration Results

Hydrographs illustrating the comparison between the HEC-HMS model output hydrograph and the FEH generated hydrographs for the following key locations are shown in Appendix E:

- Carsphairn,
- Water of Ken,
- Polharrow Burn catchment,
- Intake to Loch Ken,
- Shirmers Burn catchment to Loch Ken,
- Downstream of Clatteringshaws Loch,
- Black Water of Dee at inlet to Loch Ken,
- Downstream of outlet of Loch Ken,
- Carlingwark Lane Canal at Castle Douglas,
- Upstream of Kirkcudbright at Tongland (downstream model boundary).

It is noted that the purpose of this study (and the hydrological model) is to assess the potential application of various NFM measures at various locations in the catchment. Therefore, the absolute volume of the output flows is not as significant as the relative effects with and without NFM measures. For that reason, the calibration was not pursued extensively so as to exactly replicate the FEH generated hydrographs. However, it is considered the results of the calibration provide a reasonable level of confidence that the model is representative of the River Dee catchment and allow for a robust assessment of the implementation of NFM measures.

6. Long List of NFM Opportunities

6.1. Introduction

The identification of potential NFM measures within the catchment was undertaken following the completion of the catchment characterisation. This qualitative assessment was undertaken using best judgement to identify the potential options that could be considered for NFM upstream of the identified receptors (as detailed in Section 4).

Long listing has focussed on downstream receptors and NFM priority areas. The following sections detail the approach adopted.

6.2. Selection of Long List Options

To consider the potential NFM measures, the results of the catchment characterisation were considered in conjunction with the SEPA natural flood management maps.

The results of the long listing of NFM measures for the priority receptors are presented in the following paragraphs. The location of the long listing catchments is provided in Figure GB11820_M_011 (Appendix B).

Due to hydrological linkages, there is the potential that NFM measures being considered for a priority receptor are relevant to another receptor located downstream. Where this has been considered, this is stated within the results of the long listing assessment for individual priority receptors.

6.2.1. Carsphairn

Carsphairn is situated within the catchment of the Water of Deugh with the catchment characterisation identifying the following:

- Predominant land cover consists of coniferous woodland and acid grassland.
- The soils are defined as being permanently wet that overly relatively free draining permeable rock;
- There are a number of the morphological pressures on the rivers;
- All upstream watercourses are classed as having a Poor overall status under the requirements of the WFD;
- The SEPA identification of NFM potential has considered the following measures suitable:
 - High to medium potential for runoff reduction for all catchments;
 - High to medium potential for floodplain storage in only the Carsphairn Lane catchment (40); and
 - The opportunities for sediment management are dependent upon the morphological conditions of the river stretches.

As a result of the above, the NFM options presented in Table 6.1 were considered as part of the long listing for the catchments upstream of Carsphairn.

Table 6.1: Carsphairn Priority Receptor - Long Listing NFM Options

Upstream Contributing Catchments		NFM Action (with Main Measure Type)		
Catchment ID	Catchment Name	River Reach and Flood Storage	Runoff Reduction	Sediment Management
38	Water of Deugh	Instream Structures (large woody debris)	Riparian Woodlands Upland Drainage Modifications	River Bank Restoration
39	Bow Burn	Instream Structures (large woody debris)	Riparian Woodlands Upland Drainage	River Bank Restoration

Upstream Contributing Catchments		NFM Action (with Main Measure Type)		
			Modifications	
40	Carsphairn Lane	Instream Structures (large woody debris) Floodplain Woodland	Riparian Woodland Land and Soil Management Practices	Overland Sediment Traps
41	Water of Deugh (Benloch Burn)	Riparian Woodland Instream Structures (large woody debris)	Riparian Woodland Agricultural and upland drainage modifications Land and Soil Management Practices	Overland Sediment Traps River Bank Restoration
42	Garryhorn Burn	Washlands and offline storage ponds Floodplain Woodland Instream Structures (large woody debris)	Agricultural and upland drainage modifications Land and Soil Management Practices	Overland Sediment Traps River Bank Restoration

6.2.2. Dalry Floodplain

The Dalry floodplain is part of the Water of Ken with the catchment characterisation identifying the following:

- The predominant land cover is improved grassland;
- The Water of Ken is at high risk of fluvial flooding with the extent of linked to the extent of the floodplain;
- The soils are defined as Brown Earths and Mineral Alluvial Soils that are relatively free draining over rock with moderate to large storage capacity;
- The floodplain has been modified with the presence of bank reinforcement as well as crossing structures;
- Due to existing as well as future catchment pressures, the classification of the waterbodies ranges from Bad to Moderate;
- The SEPA identification of NFM potential has considered the following measures suitable within the Dalry Flood plain catchment (52):
 - Medium potential for runoff reduction;
 - High to medium potential for floodplain storage; and
 - The opportunities for sediment management are dependent upon the morphological conditions of the river stretches.

As a result of the above, the NFM options presented in Table 6.2 were considered as part of the long listing for the Dalry Floodplain catchment. The consideration for NFM at Dalry floodplain also takes into account the potential measures associated with Carsphairn.

Table 6.2: Dalry Floodplain Priority Receptor – Long Listing NFM Options

Upstream Contributing Catchments		NFM Action (with Main Measure Type)		
Catchment ID	Catchment Name	River Reach and Flood Storage	Runoff Reduction	Sediment Management
52	Water of Ken	Washland and offline storage ponds Floodplain Woodland	-	-

6.2.3. New Galloway

New Galloway is located within the catchment of the Mill Burn and the catchment characterisation has identified the following:

- The predominant land cover is improved grassland;
- The Mill Burn has not been mapped as being at risk of fluvial flooding with pockets of areas subject to pluvial flooding identified;
- The soils are defined as Brown Earths that are relatively free draining over rock with moderate storage capacity;
- No morphological pressures have been noted within the catchment of the Mill Burn;;
- The Mill Burn has not been classified under the requirements of the WFD;
- The SEPA identification of NFM potential has considered the following measures suitable within the Mill Burn (31):
 - Medium potential for runoff reduction;
 - No potential for floodplain storage; and
 - The opportunities for sediment management are dependent upon the morphological conditions of the river stretches.

As a result of the above, the NFM options presented in Table 6.3 were considered as part of the long listing for the New Galloway catchment. The consideration for NFM at New Galloway also takes into account the potential measures associated with catchments for the Carsphairn and the Dalry Floodplain.

Table 6.3: New Galloway Priority Receptor – Long Listing NFM Options

Upstream Contributing Catchments		NFM Action (with Main Measure Type)		
Catchment ID	Catchment Name	River Reach and Flood Storage	Runoff Reduction	Sediment Management
31	Mill Burn	Riparian Woodland	Riparian Woodland Land and Soil Management Practices Upland Drainage Modifications	Overland Sediment Traps River Bank Restoration

6.2.4. Clatteringshaws Loch

Clatteringshaws Loch is an anthropogenic feature, created as part of the Galloway Hydro Electric Scheme that is located within the catchment of the Black Water of Dee. The catchment characterisation has identified the following:

- The predominant land cover is commercial forestry, with open areas of acid grassland and bog;
- The loch and upstream watercourses have been identified as being at High risk of fluvial flooding. The extent of fluvial flooding is typical of an upland environment as it is restricted to the channels with minimal mapped breaches;
- The soils underlying the catchment are predominantly defined as being permanently wet peaty podzols, peaty rankers, peaty gleys with some areas of basin peat;
- Morphological pressures consist of the impoundment at Clatteringshaws Loch as well as a number of bridges;
- Due to the existing modified conditions of the catchment all watercourses upstream of the loch have a current WFD classification of Poor;

- The SEPA identification of NFM potential has identified the following measures to be suitable within the catchments associated with Clatteringshaws Reservoir:
 - High to medium potential for runoff reduction in all catchments;
 - High potential for floodplain storage within catchments 8 (unnamed tributaries of Clatteringshaws Reservoir) and 44 (the River Dee (with Loch Dee)); and
 - The opportunities for sediment management are dependent upon the morphological conditions of the river stretches.

As a result of the above, the NFM options presented in Table 6.4 were considered as part of the long listing for the catchments associated with Clatteringshaws Loch.

Table 6.4: Clatteringshaws Loch Priority Receptor – Long Listing NFM Options

Upstream Contributing Catchments		NFM Action (with Main Measure Type)		
Catchment ID	Catchment Name	River Reach and Flood Storage	Runoff Reduction	Sediment Management
29	Unnamed tributaries of Clatteringshaws Reservoir	Instream structures (large woody debris)	Land and Soil Management Practices Upland Drainage Modifications	River Bank Restoration
32	River Dee	Instream structures (large woody debris)	Land and Soil Management Practices Upland Drainage Modifications	River Bank Restoration
33	River Dee	Instream structures (large woody debris)	Land and Soil Management Practices Upland Drainage Modifications	River Bank Restoration
34	Craigencallie Lane	Instream structures (large woody debris)	Land and Soil Management Practices Upland Drainage Modifications	River Bank Restoration
43	Curnelloch Burn	Instream structures (large woody debris)	Land and Soil Management Practices Upland Drainage Modifications	River Bank Restoration
44	River Dee (with Loch Dee)	Instream structures (large woody debris)	Land and Soil Management Practices Upland Drainage Modifications	River Bank Restoration
49	Garrary Burn	Instream structures (large woody debris)	Land and Soil Management Practices Upland Drainage Modifications	River Bank Restoration

6.2.5. Castle Douglas and Kirkcudbright

Castle Douglas and Kirkcudbright are located further down the River Dee catchment and therefore subject to the cumulative flows of the upstream catchments. The consideration of NFM for reducing flood risk at Castle Douglas and Kirkcudbright has considered the catchments located with the study priority areas (catchments 6, 30, 35, 36, 37, 45, 46, 47 and 48 as shown in Figure GB11820_M_011; Appendix B) as well as those considered for Carsphairn, Dalry Floodplain, New Galloway and Clatteringshaws Loch.

The catchment characterisation has identified the following:

- The predominant land cover is coniferous woodland in the upland areas with the lower lying areas of the catchment mixed between grassland and arable and horticulture;
- The soils vary considerably depending upon the topographic setting within the catchment. The low lying areas of the catchment are predominantly mineral soils with the upland areas dominated by peats, podzols and gleys;
- Morphological pressures within the catchments consist of crossing structures as well as realignments and embankments;
- The current overall WFD classifications of the watercourses range from Good to Poor;
- The SEPA identification of NFM potential has identified the following measures to be suitable within the catchments associated with Castle Douglas and Kirkcudbright:
 - High and/or medium potential for runoff reduction in all catchments;
 - High potential for floodplain storage within catchments 6 (River Dee), 35 (Airie Burn), 36 (Pullhaugh Burn) and 46 (Crae Lane); and
 - The opportunities for sediment management are dependent upon the morphological conditions of the river stretches.

As a result of the above, the NFM options presented in Table 6.5 were considered as part of the long listing for the catchments associated with Castle Douglas and Kirkcudbright.

Table 6.5: Castle Douglas and Kirkcudbright Priority Receptor – Long Listing NFM Options

Upstream Contributing Catchments		NFM Action (with Main Measure Type)		
Catchment ID	Catchment Name	River Reach and Flood Storage	Runoff Reduction	Sediment Management
6	River Dee	Washlands and offline storage ponds Instream Structures (large woody debris)	Upland Drainage Modifications	River Bank Restoration River Morphology and floodplain restoration
30	Slogarie Burn	Instream structures (large woody debris)	Upland Drainage Modifications	River Bank Restoration
35	Airie Burn	Instream structures (large woody debris) Riparian Woodland	Upland Drainage Modifications Land and Soil Management Practices	River Bank Restoration Overland sediment traps
36	Pullhaugh Burn	Instream structures (large woody debris)	Upland Drainage Modifications	River Bank Restoration
37	Stroan Burn	Instream structures (large woody debris)	Upland Drainage Modifications	River Bank Restoration

Upstream Contributing Catchments		NFM Action (with Main Measure Type)		
45	Glengainoch Burn	Instream structures (large woody debris)	Upland Drainage Modifications	River Bank Restoration
46	Crae Lane	Instream structures (large woody debris)	Upland Drainage Modifications	River Bank Restoration
47	Kenick Burn	Instream structures (large woody debris)	Upland Drainage Modifications	River Bank Restoration
48	Laurieston Burn	Instream structures (large woody debris) Riparian Woodland	Land and Soil Management Practices	Overland sediment traps

6.3. Hydrological Assessment of Long List

6.3.1. Long List NFM Measure Modelling

As noted in Sections 2.4 and 6.2, the long list options were categorised under the three NFM actions, namely:

1. River Reach and Floodplain Storage,
2. Runoff Reduction,
3. Sediment Management.

Within each of these three main NFM actions, the specific NFM measures were identified as part of the long listing for each catchment. Table 6.6 below summarises the NFM actions and corresponding NFM measures identified as part of the long listing.

Table 6.6: Long List NFM Actions and Measures

NFM Actions	NFM Measures
River Reach and Floodplain Storage	Instream Structures Floodplain Woodland Riparian Woodland Washlands and Offline Storage Ponds
Runoff Reduction	Land and Soil Management Practices Riparian Woodlands Upland Drainage Modifications Agricultural and upland drainage modifications
Sediment Management	Overland Sediment Traps River Bank Restoration River Morphology and floodplain restoration

For each of the three NFM actions (i.e. River Reach and Floodplain Storage, Runoff Reduction, Sediment Management) the identified NFM measures for each receptor were included within the relevant sub-catchments of the model to replicate the inclusion of the NFM measures.

A total of 16 different physical hydrological models were created to represent the various NFM measures relevant to the receptors.

Table E.1 in Appendix E details the various models along with the relevant NFM measures and the catchments they were applied to based on the long listing.

The model(s) were then run to simulate the effect of the NFM measures on each receptor. Rainfall events for the 1:2 to 1:200 intensities, and with durations from 2hr to 22 hour were simulated for each model run.

6.3.2. Long List NFM Measure Results

The table below is an extract from Table E.2 in Appendix E and indicates the percentage reduction in flows for the respective NFM action at the specific receptor. Appendix E, Table E2 provides full details of the percentage reduction in flow at all receptors for the respective NFM actions.

Table 6.7: Long List Model Results

Receptor	NFM Action	% Reduction in Flow for Return Period			
		1 in 2	1 in 10	1 in 50	1 in 200
Carsphairn	River Reach and Floodplain Storage	10.3	7.8	6.2	5.2
	Runoff Reduction	23.4	16.9	13.0	10.6
	Sediment Management	1.5	1.6	1.6	1.3
Dalry Floodplain	River Reach and Floodplain Storage	0.6	0.6	0.4	0.4
New Galloway	River Reach and Floodplain Storage	2.0	1.3	0.0	0.7
	Runoff Reduction	7.8	6.6	4.6	4.1
	Sediment Management	2.0	1.3	0.9	0.7
Clatteringshaws Loch	River Reach and Floodplain Storage	3.3	1.1	1.4	2.4
	Runoff Reduction	16.7	9.8	7.5	7.1
	Sediment Management	2.5	0.5	0.8	1.3
Castle Douglas	River Reach and Floodplain Storage	1.0	1.2	0.6	1.2
	Runoff Reduction	1.2	1.4	0.7	1.2
	Sediment Management	1.4	1.7	1.0	1.4
Kirkcudbright	River Reach and Floodplain Storage	0.8	0.9	0.6	1.1
	Runoff Reduction	0.9	1.0	0.7	1.1
	Sediment Management	1.3	1.3	1.0	1.4

The results generally indicate that runoff reduction measures have the greatest influence in reducing peak flows. This is as expected as runoff reduction measures generally reduce the volume of water reaching the watercourses so have a greater influence on reducing flows. River reach and floodplain storage measures act to reduce flows once the flows have already accumulated within the watercourses and therefore, have less influence on reducing overall flows. Similarly sediment management measures are generally more focused at discrete problem locations within a watercourse and will have a lesser influence on overall catchment flows.

However, for Castle Douglas and Kirkcudbright, sediment management measures have a slightly greater influence on peak flows compared to runoff reduction measures. This is considered due to the distance from the receptor the NFM measures are proposed and the resultant impact this has on the timing of peak flows from the various catchments.

The NFM measures that can be applied close to a receptor result in the largest influence in flows. This can be seen from the larger percentage reductions at Carsphairn and Clatteringshaws where the NFM measures are

proposed in the catchments immediately upstream of these receptors. The further away from the NFM measure the receptor is the less influence the NFM measures have on the flow as additional inflows from other catchments dilute the effects.

The NFM measures also have a greater influence on the smaller, more frequent flood events. During the larger, less frequent events, the volume of rainfall and hence flow starts to overwhelm the NFM measures resulting in smaller percentage reductions in flow.

For Carsphairn, it can be seen that the proposed NFM measures have some benefit on flows, particularly for the runoff reduction measures, and particularly at the low return period events. It is considered that the potential reductions in flows from the implementation of NFM measures at Carsphairn would reduce the flood risk.

For Dalry Floodplain, the proposed NFM measures have very little influence on the peak flows. The NFM measures are proposed on an active floodplain and therefore, the benefits of enhancing the storage capacity of this floodplain through the implementation of NFM measures is only marginal.

For New Galloway the analysis indicates that the proposed runoff reduction measures could reduce peak flows by between 4.1% and 7.8% which is considered would be a meaningful reduction in flood risk. The runoff reduction and sediment management measures have less influence. This is considered primarily due to it being effectively a single watercourse and catchment and so measures that operate once the runoff is within the watercourse will be less influential.

For Clatteringshaws Loch, the runoff reduction measures are considered to have a significant effect on flows which would provide a meaningful reduction in flood risk. The river reach and floodplain storage measures have a lesser impact (especially when compared to Carsphairn). This difference is considered due to the smaller number and length of watercourses contributing to the Clatteringshaws catchment compared to Carsphairn.

For Castle Douglas and Kirkcudbright, the effects of NFM measures are marginal. This is due to the large size of the catchment(s) contributing to these receptors compared to the small size of NFM measures.

6.4. Sediment Management

The modelling approach to simulate sediment management has been to vary the roughness values of the watercourses. This is considered appropriate for the scale of the model and the results indicate some marginal changes in peak flows in line with what would be expected. It should also be noted that most NFM measures within the context of runoff reduction and river reach and floodplain storage, will also provide sediment management benefits. For example riparian woodland has the potential to stabilise river banks and prevent excessive erosion.

The results of the sediment management modelling indicate that this NFM action offers the least potential for flow reduction. Sediment removal is an activity that requires a licence from SEPA that is not always guaranteed to be authorised.

SEPA have advised that previous studies have shown that sediment removal is not always effective as the material removed is often re-deposited in the next flood event. Furthermore studies have shown dredging for example does not greatly improve the capacity of rivers during flood events.

A previous study by Kaya Consulting Ltd (Carsphairn Flood Study) considered sediment management as part of a detailed hydraulic model of Carsphairn. The general conclusion of that study was that sediment removal could provide a small degree of flood level reduction (circa 100mm) at the 1:200 year flow. The study recognised that sediment deposition would likely continue necessitating the need for regular sediment removal.

7. Short Listing of NFM Opportunities

7.1. Introduction

The overarching aims of the study are to identify potential measures that will reduce the flood risk to receptors in the River Dee catchment.

A detailed review of the hydrological results of the long list was undertaken and the NFM measures that were deemed to potentially provide a tangible flood risk benefit were taken forward to the short list.

The following sections detail the approach adopted.

7.2. Hydrological Impact

For each of the Long List options, the hydrological impact of the NFM measures was assessed based on the model results.

7.2.1. Receptors

Section 4.3 detailed the key receptors and the importance of these receptors. The table below is a copy of Table 4.1 and summarises the receptors and their importance.

Table 7.1: Importance of Receptors

Receptor	Importance
Carsphairn	High
Dalry Floodplain	Medium
New Galloway	Medium
Clatteringshaws Loch	Medium
Castle Douglas	Very High
Kirkcudbright	Very High

7.2.2. Magnitude of Impact

It is recognised that NFM measures provide the greatest influence on flood risk for the lower return period events. This was supported by the hydrologic modelling which focused on the 1:2, 1:10, 1:50 and 1:200 events with the results showing that NFM measures had greater influence for the lower return period events (i.e. higher reductions in flow for the 1:2 event compared to the 1:200 event).

To allow for this in the assessment of the NFM measure over the range of return periods modelled, a weighted average of the percentage change in flow was calculated. This weighted average took account of the benefit in reducing the flood risk at lower more frequent events (i.e. a higher priority was given to the higher frequency events compared to the less frequent events).

To maintain the sensitivity of the range of magnitude of impact designations, the percentage change in flow was scaled over the percentage flow reductions achieved in the project. For example, if the maximum percentage change in flow for any NFM measure assessed in the project was 20% this would attract the largest magnitude of impact, rather than assuming only a 100% reduction in flow should be assigned the largest magnitude of impact.

7.2.3. Significance of Impact

The significance of the impact was based on SEPA's Supporting Guidance (WAT-SG-67) Assessing the Significance of Impacts – Social, Economic and Environmental matrix as discussed in Section 8.1 Assessment Criteria.

7.3. Short List of NFM Measures

The assessment forms in Appendix C detail the hydrological benefit assessment undertaken. The table below summarises the results and identifies the NFM measures taken forward to the short list.

Table 7.2: Summary of Long List Assessment for Short List

Receptor	NFM Action	Tangible Hydrological Benefit. Measure Taken Forward to Short List
Carsphairn	River Reach and Floodplain Storage	Yes
	Runoff Reduction	Yes
	Sediment Management	No
Dalry Floodplain	River Reach and Floodplain Storage	No
New Galloway	River Reach and Floodplain Storage	No
	Runoff Reduction	Yes
	Sediment Management	No
Clatteringshaws Loch	River Reach and Floodplain Storage	No
	Runoff Reduction	Yes
	Sediment Management	No
Castle Douglas	River Reach and Floodplain Storage	No
	Runoff Reduction	No
	Sediment Management	No
Kirkcudbright	River Reach and Floodplain Storage	No
	Runoff Reduction	No
	Sediment Management	No

The following table details the four NFM actions forming the short list and Figure GB11820_M_012 (Appendix C) illustrates the catchments these measures would apply to.

Table 7.3: Short List of NFM Actions

Receptor	NFM Action
Carsphairn	River Reach and Floodplain Storage
	Runoff Reduction
New Galloway	Runoff Reduction
Clatteringshaws Loch	Runoff Reduction

7.4. Site Reconnaissance Surveys

Following the completion of the short listing exercise, further surveys were undertaken to ground truth the proposed options. The following provides a summary of a number of the observations made during the completion of the surveys. It is acknowledged that the short listed options will be subject to further investigations to fully determine the suitability and extent of proposed NFM options.

7.4.1. Summary of survey

A reconnaissance level survey was completed for specific reaches and areas shortlisted to be considered for NFM to allow the environmental context of the catchment to be confirmed. The survey identified important geomorphological features and fluvial processes that have helped guide the NFM short listing proposals.

The survey covered key sections within the catchments upstream of Carsphairn and New Galloway. As a result of the potential extent of instream structures and upland drainage modifications it was not practical to survey all identified areas in entirety. However, the survey did ensure that representative watercourses and ground conditions was surveyed. Further details on the surveys undertaken are presented in the following paragraphs.

A photographic log of the survey results are provided in Appendix F.

7.4.2. Carsphairn

The areas considered for NFM have been divided into five distinct survey areas based on the catchments provided in Figure GB11820_M_013. A detailed photographic log of the survey results is also provided in Appendix F.

Area 1

Area 1 covers exclusively the Garryhorn Burn catchment (42), and includes proposals for runoff reduction as well as river reach and floodplain storage. From the observations made during the site reconnaissance the key catchment characteristics are highlighted below:

- Upland catchment comprising open heathland and grassland;
- Evidence of historic mine working;
- Larger channels incised into glacial deposits, unless in steeper ground where incised into bedrock;
- Smaller channels often incised into peat with a few not being visible at all. These ephemeral channels are likely to move locations quickly making in-channel modification potentially problematic;
- Main channel of Garryhorn Burn varies in width, with varying bank width and material;
- Apart from the higher ground extensive areas have been artificially drained with vertical ditches dug into the peat.

Examples of the key catchments characteristics are presented in Photographs 7.1 – 7.4.

Source: *Natural Power*



Photograph 7.1: Garryhorn Burn devoid of riparian woodland and wide flood plain



Photograph 7.2: Minor tributary within catchment of Garryhorn Burn (suitable for in-stream debris)



Photograph 7.3: Garryhorn Burn devoid of riparian woodland with extensive areas of open ground.



Photograph 7.4: Bed material of Garryhorn Burn

Area 2

Area 2 covers the lower reaches of the Carsphairn Lane catchment (40) which has identified runoff reduction and river reach and floodplain storage measures. From the observations made during the site reconnaissance the key catchment characteristics are highlighted below:

- Channel slope very low ~2-5 degrees;
- Channel is sinuous and meandering;
- Bedload is silt and sand with some gravels, with lower reaches predominantly pebbles of various sizes;
- Very few boulders protruding water surface;
- Banks are vegetated and occasionally tree lined. Combination of soil and peat;
- Nearby slopes often artificially drained by vertical drainage channels. Channels are incised into the peat; and
- Extensively flat and terraced with a lot of water saturated ground.

Examples of the key catchments characteristics are presented in Photographs 7.5 – 7.6.

Source: Natural Power



Photograph 7.5: Broad floodplain at Carsphairn with evidence of stock control measures



Photograph 7.6: Broad open floodplain with extensive areas of open ground

Area 3

Area 3 covers the lower reaches of the Water of Deugh, with contribution from the Benloch Burn and Polsue Burn (catchment 41) and includes proposals for runoff reduction as well as river reach and floodplain storage. From the observations made during the site reconnaissance the key catchment characteristics are highlighted below:

- Main channel has a slope of 5 degrees with a high to moderate flow speed;
- Channel is braided with sequences of gravels, cobbles and boulders;
- Channel has a very high sediment yield with gravel banks and bars and is incised only on river bend outside banks;
- Channel is 7m wide with braided area being 25m in diameter;
- Banks are grass, soil and gravel however significant erosion and bank collapse is happening in some places; and
- Catchment hill slopes are steeper closer to the river (where note terraced) but predominantly gently sloping. Visible vertical drainage ditches which are likely to be artificial.

Examples of the key catchments characteristics are presented in Photographs 7.7 – 7.10.

Source: Natural Power



Photograph 7.7: Water of Deugh downstream of the A713



Photograph 7.8: Wide channel of the Water of Deugh, with limited vegetation (evidence bank erosion)



Photograph 7.9: Tributary of the Benloch Burn with potential for placement for instream structures as well as riparian woodland



Photograph 7.10: Benloch Burn with potential for riparian woodland

Area 4

Area 4 encompasses the upper headwaters of Carpshairn Lane, including Lamford Burn and Meadowhead Burn, which has identified runoff reduction and river reach and floodplain storage measures. From the observations made during the site reconnaissance the key catchment characteristics are highlighted below:

- Narrow upland channels with a slope of 5-10 degrees which is incised into the peat and tussocks. Flow speed is moderate;
- Channels range from ~0.1-0.5m wide and of similar depth with plunge pools and small falls;
- Channel morphology of the lower Lamford Burn is gorge like and is deeply incised into bedrock / glacial sediments to ~10m, with grass growing most of the way down to the channel;
- Channel has falls and plunge pools and becomes more sinuous further downstream; and
- Evidence of artificial drainage ditches across the hill sides feeding into the channel.

Examples of the key catchments characteristics are presented in Photographs 7.11 – 7.12.

Source: Natural Power



Photograph 7.11:Incised channel of the Lower Lamford Burn (potential for placement of instream structures and riparian woodland)



Photograph 7.12: Headwaters of the Lamford Burn

Area 5

Area 5 encompasses the Water of Deugh, upstream of its confluence with the Polsue Burn (catchments 38 and 39). There are significant areas of commercial forestry at various stages of development. The consideration of upland drainage modifications have focussed on areas where there is known felling taking place as well as areas where there is the potential for felling should consents be granted for proposed renewable energy projects (e.g. Windy Standard III Wind Farm).

Due to the upland nature of the catchment, there has been significant consideration for the placement of instream structures. Due to the extent of the area, surveys focussed on a limited selection of locations

The key observations from the site reconnaissance are:

- Extensive areas have been felled with the potential for drainage channels to accommodate drainage modifications. However, it is also noted that there is likely to be forestry debris existing within these channels;
- Channels are often small, with plunge pools and falls;
- Channel bedload is mainly fine sediments and is discoloured by the peat; and
- Debris often located within the channels that have the potential to reduce the flow rate.

Examples of the key catchments characteristics are presented in Photographs 7.13 – 7.15.

Source: Natural Power



Photograph 7.13: Examples of recent clearfell



Photograph 7.14: Example of clearfell



Photograph 7.15: Hydromorphological conditions of Goat Burn (suitable for instream structures and riparian woodland)

7.4.3. New Galloway

The potential for NFM within the catchment of Mill Burn (catchment 31) has focussed on the potential for runoff reduction. The key observations from the site reconnaissance confirm the following:

- The channel varies in width, with the headwaters ~0.2 m with the main channel of the Mill Burn being >1 m;
- No evidence of bank erosions encountered and bed materials consists of pebbles and boulders;
- Catchment is predominantly used for livestock grazing and consists of grassland;
- Channel is generally incised with banks being heavily vegetated, evidence of sparse tree growth.

Examples of the key catchments characteristics are presented in Photographs 7.16 – 7.18.

Source: Natural Power



Photograph 7.16: Catchment land use (with field boundary, potential for hedgerow planting)



Photograph 7.17: Hydromorphological conditions of the Mill Burn

8. Initial Option Appraisal

The four NFM actions identified in the short list (summarised in the table below) were taken forward to the Initial Option Appraisal stage.

Table 8.1: Short List of NFM Actions

Receptor	NFM Action
Carsphairn	River Reach and Floodplain Storage Runoff Reduction
New Galloway	Runoff Reduction
Clatteringshaws Loch	Runoff Reduction

The assessment forms in Appendix C, detail the option appraisal undertaken and the following sections detail the methodology adopted in the appraisal of each NFM action. Figure GB11820_M_013 (Appendix D) illustrates the catchments and the NFM measures considered.

The initial option appraisal considered the following criteria:

- Feasibility / Engineering,
- Land Management,
- Hydrological,
- Environmental,
- Social.

8.1. Assessment Criteria

An options appraisal was undertaken to determine which natural flood management measures would be most effective in each catchment. This appraisal followed the principles of SEPA's Natural Flood Management Handbook. The handbook notes that Natural Flood Management rarely delivers benefits to flooding alone and considers that the wider benefits that NFM measures provide should be included in the assessment. This is also a key consideration in Scottish Government guidance which refers to this service when making land management decisions.

8.1.1. Impact Assessment Significance

The project team adopted SEPA's Supporting Guidance (WAT-SG-67) Assessing the Significance of Impacts – Social, Economic and Environmental to determine the significance of the impacts. The following matrix was used alongside the professional judgement based on the projects teams experience of working on similar environmental and renewable energy projects and knowledge of the local area to determine the potential impacts and whether they were positive or negative.

The significance of an impact is determined by combining the importance of the receptor and the magnitude of the impact.

Source: SEPA

Table 3 Indicative guide to assessing the significance of an impact

Combining assessments of the magnitude of impact with assessments of the importance of the affected social, economic or environmental factor						
Importance of impacted factor	Magnitude of impact					
	Negligible/ V Minor	V Small	Small	Medium	Large	V Large
Very low / negligible	N	N	N	N	N	N
Low	N	VL	VL	L	M	M-H
Medium	N	VL	L	M	M-H	H
High	N	VL	M	H	H-VH	VH
Very High	N	L	M-H	H-VH	VH	VH

Key to Table 3:

"N" means of negligible significance;
 "VL" means of very low significance;
 "L" means of low significance;
 "M" means of moderate significance;
 "H" means of high significance; and
 "VH" means of very high significance.

Figure 8.1: Guide to assessing significance

The following sections define how the importance of the receptor and the magnitude of the impact were determined for this appraisal. For some of the criteria adopted in the appraisal (e.g. feasibility/engineering, land management and social), it was not appropriate to apply the above matrix and the following sections outline the qualitative assessment undertaken for these criteria.

8.1.2. Feasibility / Engineering

The feasibility and engineering assessment considered factors such as:

- **Feasibility issues** – landowner acceptance and sources of funding are considered the two biggest factors affecting the feasibility of the proposed NFM options. At this stage in the project these factors are not fully known and will need to be considered as the project progresses and more definitive option(s) are identified in consultation with landowners.
- **Future Adaptation** – this considers the potential impact or restriction the implementation of a NFM measure may have on future flood mitigation works. The assessment was qualitative and considered the nature and location of the proposed NFM option and how that may impact on any future flood mitigation works.
- **NFM Measure Benefit Realisation** – this considered the likely timescale for the particular NFM measures, once installed, to actually start providing the flood mitigation benefit. For example, the installation of a woody debris dam would provide its intended flood mitigation benefit almost instantly whereas planting trees may take several years before the trees become mature enough to begin reducing flood flows. The assessment was based on a qualitative approach.
- **Timescales of Works** – this considered how long it would take to install the NFM option(s) being considered. The assessment is qualitative based on no external restrictions such as reaching landowner agreement, funding, etc. It should be noted that timescales are important considerations in the landowner discussions and the projects objectives / funding.

- **Estimated Costs to Deliver** - cost estimates are based on project team experience and a review of case studies delivering similar measures, applying these to the number and extent of measures proposed in the whole catchment. Detailed project specific costings can only be calculated in the detailed design phase once projects are identified at specific locations and the site specific engineering, environmental and hydrological requirements are fully defined.

The table below outlines details the estimated costs for delivery of the NFM measures considered.

Table 8.2: Estimated Costs for NFM Measures

NFM Measures	Estimated Cost Range	Notes
Hedgerow Planting (lowland)/ Low Density Native Planting (upland)	£5 / m	Depending on landscape, species and spacings (inc plant protection)
Floodplain / Riparian Woodland Planting	£3k to £5k / Ha	Site specific and depends on the species to be planted.
Stock Proof Fencing	£4 / metre	Fencing costs typically reduce the longer the fencing requirements and also depend on the type of fencing required. Deer fencing will be typically around £8/m
Settlement Ponds	£1k / pond	Site specific and depends on size, terrain and flow controls.
Instream Structures (woody debris)	£100 to £1k / dam	Site specific and depends on ground conditions, engineering needed felling requirements and size of watercourse. Typically installed at spacing of circa 200m.
Upland Drainage Modifications	£30 / Ha	Site specific and will need suitable ditches to be identified and a suitable drainage regime designed.

Compensation for loss of grazing, disruption or loss of control during construction, etc has not been considered. It is likely these costs would be dependent on the outcome landowner negotiations. On marginal land this may not be an issue or will be low cost but for larger areas compensation may be needed.

For each of the proposed NFM options the costs were built up based on the above cost estimates and the number/area/extent of NFM measures proposed to determine the total estimated cost of the proposed NFM option. From the total cost estimate for a NFM option, the appraisal considered the thresholds shown in

Table 8.3 below. All costs exclude consultancy fees and landowner negotiation.

Table 8.3: Project Costs Ranking

Estimated Cost	Cost Rank
0 to £150k	Low
£151k to £550k	Medium
>£550k	High

- **Maintenance Costs** - this considered the long term maintenance and management costs that would be required to retain the effectiveness of the NFM measure. As the involvement of landowners or contractors could require long term agreements or financial mechanisms, at this stage, only a qualitative assessment has

been undertaken to estimate the likely long term maintenance and management costs associated with the NFM options.

- **Health & Safety** – this considered the health and safety issues likely to be encountered for the installation and maintenance of the proposed options. The assessment is based on a qualitative approach.

8.1.3. Land Management

The option appraisal considered the potential loss of income or loss of control of land management. Due to the complexities of landowner discussions these were not quantified. At this stage, land management issues have been based on land take and the practicalities of installing and managing the proposed measures.

As outlined in Section 9 below, landowners have been introduced to the project but no agreements are in place and detailed negotiation has not yet begun.

8.1.4. Hydrological

The hydrological benefit was undertaken as part of the short listing based on the methodology detailed in Section 7.2.

Importance of Receptors

The methodology in Section 7.2 detailed the importance of the identified receptors as summarised in the table below.

Table 8.4: Importance of Receptors

Receptor	Importance
Carsphairn	High
Dalry Floodplain	Medium
New Galloway	Medium
Clatteringshaws Loch	Medium
Castle Douglas	Very High
Kirkcudbright	Very High

Magnitude of Impact

As detailed in Section 7.2, the magnitude of the impact was based on the percentage change in flow due to the implementation of the relevant NFM measure in the catchment(s).

8.1.5. Environmental

NFM measures can have a positive impact on environmental receptors, including biodiversity, water quality; reduced soil erosion as well as encouraging carbon sequestration. NFM can restore ecosystems to help support a wider range of habitats and species. The improvements to water quality will improve instream habitats and potentially increase connectivity allowing greater movement of flora and fauna.

In general, NFM measures should improve ecosystems by increasing their capacity to respond to the effects of climate change without detriment to their functionality. These wider benefits are an important consideration in the appraisal because they make a positive environmental impact which extends beyond just focusing on the management of flood risk.

The assessment used the information collated as part of the baseline studies to consider potential effects of the measures on:

- Flora & Fauna – in the absence of detailed site surveys, the assessment utilises published and/or publically available datasets to determine the sensitivity of the habitats and how NFM could impact upon the movement and/or extent of flora and fauna;
- Soil – the assessment considers the classification and/or status of soils, including peat, to determine how NFM could improve stability and/or carbon sequestration. Utilisation of land use maps, soil classification maps and carbon soil classifications have been used to determine the sensitivity of the soils underlying the catchments;
- Water – through the utilisation of the SEPA RBMP and morphological pressures database the assessment considers how NFM can impact upon the current WFD status of waterbodies;
- Use of Natural Resources – the assessment considers if the intended NFM measures would rely on natural resources or more engineered materials.

Importance of Receptor

The importance of the receptor was determined with respect to whether the areas was designated, the level of that designation and whether it would be directly or indirectly affected by the proposed measures. The importance considered:

- Flora and Fauna:
 - Designated sites, including Special Areas of Conservation, Special Protection Areas and Sites of Special Scientific Interest;
 - The presence of invasive species;
 - Records of species via review of the National Biodiversity network;
 - The likely presence of salmon and sea trout within watercourses;
- Soils::
 - Consideration of existing land use;
 - Soils classification – presence and extent of peat and/or peaty soils;
 - Carbon soils classification – presence and extent of priority peatland habitats (classes 1 and 2)
- Water:
 - Consideration of the current and future RBMP status of waterbodies; and
 - Consideration of the current and potential future natural and anthropogenic pressures on waterbodies.

Professional judgement was then used to establish the potential influences of NFM on the environmental receptors. This has included positive and negative impacts, as for example the installation of in-stream structures has the potential to inhibit movement of fauna.

Magnitude of Impact

The assessment of the effects of the proposed measures on the aims of the designation and the wider effects the measures could have on social and economic interests determined the magnitude. For instance, the magnitude of impact was determined through assessment of the potential cumulative effect of the measures on the areas Water Framework Directive status.

8.1.6. Social

The measures can have a positive impact on quality of life through improvements in bio diversity, landscape or recreation. They can help to enhance the rural environment and potentially support recreational activities or create educational tools as part of a community led approach to implementing the project.

The assessment was qualitative based on our understanding of the local area to determine potential effects of the measures on:

- Landscape,
- Cultural Heritage,

- Social Aspects.

8.2. Appraisal of Options

The above assessment methods were applied to each of the short list options as outlined in the following sections. The individual assessments included in Appendix C provide details of the assessment.

8.2.1. Carsphairn Runoff Reduction

This option includes:

- Land and soil management practices (catchments 40, 41 & 41) – e.g. Low density native planting buffers.
- Riparian woodland (catchments 38, 39, 40, 41 & 42).
- Upland drainage modifications (catchments 38, 39, 40, 41 & 42) – e.g. drain blocking.

Feasibility / Engineering

The proposed options would be primarily located in the upper reaches of the catchment and as such it is not anticipated there would be any issues with the implementation of future flood mitigation works. Any future flood mitigation works would likely be focused on the immediate environs to the village of Carsphairn, aimed at protecting individual properties and businesses.

While some runoff reduction measures such as upland drain blocking would have an immediate benefit, many of the measures would take a longer timescale for the benefit to be realised. Planting of low density native buffer areas could take several years to reach maturity and the benefits for runoff reduction to be realised.

It is anticipated that the runoff reduction measures could be implemented within a reasonable short timeframe of around 12 to 18 months depending on seasonal circumstances. Planting low density native planting buffers should be implemented to suit their optimum planting time. These factors may extend the overall timescales for implementation towards 18 months.

As detailed in Section 7.4.2, the Carsphairn measures were divided into five distinct areas. The anticipated costs to install the proposed measures for each area and in summary are presented in the tables below. Please note that for Riparian Woodland SEPA NFM guidance is for a 30 m buffer however for practical implementation at this stage of the costings we have assumed a 15 m buffer to account for forestry grants, topography and landowner discussions.

Table 8.5: Carsphairn runoff reduction area 1

NFM Measures			Dimensions	Estimated Cost	Total Cost
Low density Native Planting Buffers			4km	£5 / m	£20,000.00
Stockproof Fencing			8 km (based on fencing either side of buffers, excludes Riparian fencing)	£4 / m stock fencing	£32,000.00
Riparian woodland			(based on 15 m buffer either side of watercourse) – 22 Ha	£4,000 / Ha	£88,000.00
Upland drainage modifications			352 Ha	£30 / Ha	£10,560.00
Sub Total					£150,560.00

Table 8.6: Carsphairn Runoff Reduction Area 2

NFM Measures	Dimensions	Estimated Cost	Total Cost
Low density Native Planting Buffers	2.5km	£5 / m	£12,500.00.
Stockproof Fencing	5 km	£4 / m stock fencing	£20,000.00
Sub Total			£32,500.00

Table 8.7: Carsphairn Runoff Reduction Area 3

NFM Measures	Dimensions	Estimated Cost	Total Cost
Riparian woodland	(based on 15 m buffer either side of watercourse) – 11 Ha	£4000 / ha	£44,000.00
Low density Native Planting Buffers	4km	£5 / m	£20,000.00
Stockproof Fencing	8km	£4 / m stock fencing	£32,000.00
Upland drainage modifications	466 Ha	£30 / Ha	£13,980.00
Sub Total			£109,980.00

Table 8.8: Carsphairn Runoff Reduction Area 4

NFM Measures	Dimensions	Estimated Cost	Total Cost
Upland drainage modifications	230 Ha	£30 / Ha	£6,900.00
Riparian woodland	(based on 15 m buffer either side of watercourse) – 16 Ha	£4000 / Ha	£64,000.00
Sub Total			£70,900.00

Table 8.9: Carsphairn Runoff Reduction Area 5

NFM Measures	Dimensions	Estimated Cost	Total Cost
Riparian woodland	(based on 15 m buffer either side of watercourse) – 23 Ha	£4000 / ha	£92,000.00
Upland drainage modifications	1528 Ha	£30 / Ha	£45,840.00
Sub Total			£137,840.00

Table 8.10: Carsphairn Runoff Reduction Summary Estimated Cost

Area	Estimated Cost
1	£150,560
2	£32,500
3	£109,980
4	£70,900
5	£137,840
Option Total	£501,780.00

Overall the estimated cost £501,780.00 which, in accordance with

Table 8.3, the project cost rank is considered to be Medium.

Once implemented it is considered maintenance costs would be low. Generally, the measures should be left to grow and mature on their own with little or no maintenance required. Upland drain blocking would require ongoing monitoring and checks on their effectiveness.

The main health and safety risks which will need to be managed are considered to include:

- Remote working in an upland environment.
- Drain blocking will require working within watercourses and potentially very soft ground.

Land Management

More detailed negotiations need to be undertaken with all landowners to fully understand the potential financial impact and loss of control.

Hydrological

The results and benefit outcome of the hydrological assessment are summarised in Table 8.11 below.

Table 8.11: Carsphairn Runoff Reduction Hydrological Results

Description	Compliance Point	% Reduction in Flow for Return Period				Benefit Outcome
		1 in 2	1 in 10	1 in 50	1 in 200	
Carsphairn: Runoff Reduction	Carsphairn	23.4	16.9	13.0	10.6	Very High
	Dalry Floodplain	6.0	4.8	4.3	3.6	Low
	New Galloway	5.7	4.4	3.9	3.3	Low
	Clatteringshaws Loch	0.0	0.0	0.0	0.0	N/A
	Castle Douglas	2.9	2.2	1.8	1.7	Low
	Kirkcudbright	2.6	2.2	1.9	1.7	Low

Environmental

Runoff reduction measures can provide a number of environmental benefits, however it is acknowledged that the realisation of these benefits can be spatially and temporally dependent upon the scale of implementation of specific measures. NFM are unlikely to change the WFD status of the overall catchment due to existing and potential future catchment pressures.

The consideration of upland drainage modifications and subsequent rewetting of habitat can, in time, help improve the quality and diversity habitat. Upland drain blocking of previously forested areas and areas with land drainage could also support Peatland Action¹, where the sequestration of carbon via rewetting of damaged peatlands is a key deliverable.

Runoff reduction via riparian woodland and low density native planting buffers could also provide additional environmental benefit by improving the diversity of habitat within the catchment. These measures also have the potential to reduce erosion through root systems providing increased stability to soils and bank stabilisation.

Landscape was classed as Medium due to the presence of the Regional Scenic Area, the effects of the measures are localised therefore benefits in terms of landscape character are very low.

As an upland environment, low density native planting buffers are considered to be a more appropriate measure. Low density native planting buffers have wide ranging benefits to wildlife, providing food and shelter and providing networks or corridors for the movements of animals and insects. They also help the wider environment by adding character to the landscape, providing a strong sense of place through their continuity and signs of the changing seasons. Similarly riparian planting using native species will benefit biodiversity and add to the landscape character.

These measures implemented at a local scale are unlikely to cause significant impact on the overall landscape character of the catchment however, it is noted that localised effects may be higher than the regional perspective that has been assessed in this report*.

None of the measures will directly impact any designated cultural heritage interests (ref section 5.1.6). Any non-inventory interests would be assessed in the detailed design and the NFM measures microsituated to avoid significant impacts.

A summary of the benefits on environmental receptors is presented in

Table 8.12.

Table 8.12: Summary of environmental benefits (Carsphairn runoff reduction)

Environmental Receptor	Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome
Flora and Fauna	High	Medium	High
Soil	Medium	Medium	Moderate
Water	High	Medium	High
Use of natural resources	High	Medium	High
Landscape	Medium	Low Small	Very low*
Cultural heritage	N/A	N/A	N/A

¹ SNH Peatland Action - <http://www.snh.gov.uk/climate-change/taking-action/carbon-management/peatland-action/information-for-applicants/>

Social

As shown above, the implementation of these measures will ultimately help to reduce flood risk to the Carsphairn Community which is considered to be a significant benefit. Improvements in biodiversity will create a better connection to the environment and improve landscape character, giving a greater sense of place.

It may also be possible to incorporate recreational activities into the measures or assist learning and development for schools and other interested groups keen to understand the measures, their benefits, and their long term evolution.

In the longer term they may benefit tourism, attracting people interested in the measures, the outcomes of the project and the potential wildlife watching opportunities they generate.

Overall it is considered there would be a social benefit associated with the implementation of the NFM measures.

8.2.2. Carsphairn River Reach and Floodplain Storage

This option includes:

- Instream structures (catchments 438, 39, 40, 41 & 42) – e.g. woody and porous dams.
- Floodplain woodland (40, 41 & 42)
- Riparian woodland (catchments 38, 39, 40, 41 & 42).
- Washlands and offline storage ponds (catchment 42).

Feasibility / Engineering

The proposed options would be primarily located in the upper reaches of the catchment and as such it is not anticipated there would be any issues with the implementation of future flood mitigation works. Any future flood mitigation works would likely be focused on the immediate environs to the village of Carsphairn, aimed at protecting individual properties and businesses.

While some river reach measures such as instream structures would have an immediate benefit, many of the measures would take a longer timescale for the benefit to be realised. Planting woodland will take several years to reach a mature enough state to influence the water cycle and provide the NFM benefits.

It is anticipated that the runoff reduction measures could be implemented within a reasonable short timeframe of around 6 to 12 months depending on seasonal circumstances.

As detailed in Section 7.4.2, the Carsphairn measures were divided into five distinct areas. The anticipated costs to install the proposed measures for each area and in summary are presented in the tables below.

Table 8.13: Carsphairn River Reach and Floodplain Storage Area 1

NFM Measures	Dimensions	Estimated Cost	Total Cost
Riparian woodland	(based on 15 m buffer either side of watercourse) – 21.3 ha	£4,000 / ha	£85,200
Instream structures	10,500 m	£200 / structure	£10,500
Washland and offline storage ponds	3 areas (10m ³ each)	£1,000 / pond	£3,000
Sub Total			£170,700

Table 8.14: Carsphairn River Reach and Floodplain Storage Area 2

NFM Measures	Dimensions	Estimated Cost	Total Cost
Floodplain woodland	433.3 ha	£4,000 / ha	£173,200
Instream structures	8600m	£200 / structure	£8,600
Sub Total			£181,800

Table 8.15: Carsphairn River Reach and Floodplain Storage Area 3

NFM Measures	Dimensions	Estimated Cost	Total Cost
Riparian woodland	(based on 15 m buffer either side of watercourse) – 11 ha	£4,000 / ha	£44,000
Instream structures	8,800m	£200 / structure	£8,800
Sub Total			£52,800

Table 8.16: Carsphairn River Reach and Floodplain Storage Area 4

NFM Measures	Dimensions	Estimated Cost	Total Cost
Instream structures	18,000m	£200 / structure	£18,000
Riparian woodland	(based on 15 m buffer either side of watercourse) – 15.6 ha	£4,000 / ha	£62,400
Sub Total			£80,400

Table 8.17: Carsphairn River Reach and Floodplain Storage Area 5

NFM Measures	Dimensions	Estimated Cost	Total Cost
Instream structures	107,000m	£200 / structure	£107,000
Riparian woodland	(based on 15 m buffer either side of watercourse) – 22.8 ha	£4,000 / ha	£91,200
Sub Total			£198,200

Table 8.18: Carsphairn River Reach and Floodplain Storage Estimated Cost Summary

Area	Estimated Cost
1	£170,700
2	£181,800
3	£52,800
4	£80,400
5	£198,200
Option Total	£683,900

Overall the estimated cost is £683,900 which, in accordance with Table 8.3, the project cost rank is considered to be High.

Once implemented it is considered maintenance costs would be low. Generally, the measures should be left to grow and mature on their own with little or no maintenance required. Instream structures would require ongoing monitoring and checks on their effectiveness.

The main health and safety risks which will need to be managed are considered to include:

- Remote working in an upland environment.
- Instream structures will require working within watercourses and potentially in areas of steep and uneven terrain.
- The creation of washlands and storage ponds will likely require some significant excavation works with large plant and machinery.

Land Management

More detailed negotiations need to be undertaken with all landowners to fully understand the potential financial impact and loss of control..

Hydrological

The results and benefit outcome of the hydrological assessment are summarised in Table 8.19 below.

Table 8.19: Carsphairn River Reach and Floodplain Storage Hydrological Results

Description	Compliance Point	% Reduction in Flow for Return Period				Benefit Outcome
		1 in 2	1 in 10	1 in 50	1 in 200	
Carsphairn: River Reach and Floodplain Storage	Carsphairn	10.3	7.8	6.2	5.2	High
	Dalry Floodplain	3.8	3.1	2.7	2.6	Very Low
	New Galloway	3.4	2.9	2.4	2.3	Very Low
	Clatteringshaws Loch	0	0	0	0	N/A
	Castle Douglas	2.0	1.6	1.1	1.2	Negligible
	Kirkcudbright	1.7	1.5	1.1	1.2	Negligible

Environmental

River reach and floodplain storage measures can provide a number of environmental benefits. However it is acknowledged that the realisation of these benefits can be spatially and temporally dependent upon the scale of implementation of specific measures

It is acknowledged that instream structures could have the potential to negatively impact upon the passage of fauna along stretches of watercourses. However, limiting the implementation of these measures to upland watercourses and tailoring the design to ensure flows in normal conditions are maintained will reduce any perceived negative impact.

Floodplain and/or riparian woodland and washland and/or offline storage ponds provide benefits by improving habitat diversity. The attenuation of runoff offered by the proposed measures could also reduce soil erosion and allow settlement of silt within the upper reaches of watercourses.

NFM are unlikely to change the WFD status of the overall catchment due to existing and potential future catchment pressures. It is also acknowledged that the measures will not require alteration of existing structures so hydropower operations are unlikely to be affected.

Landscape was classed as Medium due to the presence of the Regional Scenic Area, the effects of the measures are localised therefore benefits in terms of landscape character are very low. This should not detract from the potential benefits to the local landscape. Riparian planting using native species and storage ponds could add to the character of the local area*.

None of the measures will directly impact any designated cultural heritage interests (ref section 5.1.6). Any non-inventory interests would be assessed in the detailed design and the NFM measures micrositied to avoid significant impacts.

A summary of the benefit on environmental receptors is presented in Table 8.20.

Table 8.20: Summary of Environmental Benefits (Carsphairn River Reach and Floodplain Storage)

Environmental Receptor	Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome
Flora and Fauna	High	Medium	High
Soil	Medium	Medium	Moderate
Water	High	Small	Very low
Use of natural resources	High	Medium	High
Landscape	Medium	Low Small	Very low*
Cultural heritage	N/A	N/A	N/A

Social

As shown above, the implementation of these measures will ultimately help to reduce flood risk to the Carsphairn Community which is considered to be a significant benefit. Improvements in biodiversity will create a better connection to the environment and improve landscape character, giving a greater sense of place.

It may also be possible to incorporate recreational activities into the measures or assist learning and development for schools and other interested groups keen to understand the measures, their benefits, and their long term evolution.

In the longer term they may benefit tourism, attracting people interested in the measures, the outcomes of the project and the potential wildlife watching or fisheries opportunities they generate.

Overall it is considered there would be a social benefit associated with the implementation of the NFM measures.

8.2.3. Clatteringshaws Runoff Reduction

This option includes:

- Land and soil management practices (catchments 29, 32, 33, 34, 43, 44 & 49) – e.g. alteration to commercial forestry drainage practices to comply with current guidance (i.e. Forests and Water – UK Forestry Standard Guidelines).
- Upland drainage modifications (catchments 29, 32, 33, 34, 43, 44 & 49) – e.g. drain blocking in areas provided in the National Forest Inventory identified as “Felled”, “Open”, “Unplantable or bare” and “Unplanted Streambanks”..

The land around Clatteringshaws is owned by the Forestry Commission. They publish a range of UK Forestry Standard Guidelines that outline the approach of UK Governments to sustainable forest management and provide a basis for regulation and monitoring. These guidelines include Forests and Water which recognises the importance of water quality and the protection from flooding, soil erosion and aquatic species as well as the Practice Guide² for deciding future management options for afforested deep peatland. Natural Flood Management plays an important part in achieving these standards which have to be adhered to by all forestry operators.

Through the management of the commercial forestry around Clatteringshaws, the Forestry Commission will implement the requirements of their Forests and Water guidelines. Typically commercial forest areas planted prior to the publication of the Forests and Water guidelines would not incorporate the measures detailed in the guidelines. However, when mature forest areas are felled and re-planted they will adhere to the Forests and Water guidelines and incorporate measures to reduce flood risk and reinstate the hydrological cycle back to a more natural state in accordance with the principles of natural flood management.

In areas of open ground or where there are opportunities to restore previously afforested areas it is recommended that consideration of upland drainage modifications take into account the requirements of Peatland Action¹ and Forestry Commission guidance on deciding the future management options for afforested deep peatland².

As such, over time, the NFM measures proposed within the Clatteringshaws catchment will be implemented by the Forestry Commission as they fell the older blocks and re-plant incorporating their Forests and Water guidelines, assess the requirements through the management requirements of previously afforested areas in deep peat² and consider the opportunities available through Peatland Action¹..

The NFM measures proposed within this report for Clatteringshaws take account of the long term Forestry Commission strategy that will implement some of the NFM measures considered. However, it has been assumed that the costs of this would be borne by the Forestry Commission. Therefore, the costs presented relate only to the NFM measures considered for the non-forested areas of the Clatteringshaws catchment.

Feasibility / Engineering

Land Management

The land is general commercial plantation forestry and therefore, any NFM measures would need to be carefully integrated into the forest plan in consultation with the Forestry Commission.

Hydrological

The results and benefit outcome of the hydrological assessment are summarised in Table 8.21 below.

² Forestry Commission Scotland (2015), *Deciding future management options for afforested deep peatland*. Forestry Commission Scotland Practice Guide

Table 8.21: Clatteringshaws Runoff Reduction Hydrological Results

Description	Compliance Point	% Reduction in Flow for Return Period				Benefit Outcome
		1 in 2	1 in 10	1 in 50	1 in 200	
Clatteringshaws Loch	Carsphairn	0	0	0	0	N/A
	Dalry Floodplain	0	0	0	0	N/A
	New Galloway	0	0	0	0	N/A
Runoff Reduction	Clatteringshaws Loch	16.7	9.8	7.5	7.1	High
	Castle Douglas	2.8	1.9	1.1	1.1	Low
	Kirkcudbright	2.6	1.8	1.2	1.1	Low

Environmental

Measures have focussed on improvements to land and soil management practices as dictated by the Forest and Water Guidelines and deciding future management options for afforested deep peatland as well as upland drainage practices. Should the Forestry Commission consider the proposals a number of benefits include improvement to surrounding habitats and existing designated sites.

The consideration of upland drainage modifications and subsequent rewetting of habitat can, in time, help improve the quality and diversity habitat. Upland drain blocking of land within the catchment of Clatteringshaws reservoir, including open and previously forested areas could also support Peatland Action¹, where the sequestration of carbon via rewetting of damaged peatlands is a key deliverable.

The NFM measures are unlikely to improve the WFD status of the catchment due to the existing catchment pressures. However, any further forestry operations will be undertaken cognisant of industry good practice, including but not limited to the Forests and Water Guidelines³. Works compliant with this guidance will limit drainage and help slow the flow of runoff from forested areas, thus providing benefits by reducing soil erosion.

A summary of the benefits on environmental receptors is presented in Table 8.22.

Table 8.22: Summary of Environmental Benefits (Carsphairn River Reach and Floodplain Storage)

Environmental Receptor	Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome
Flora and Fauna	High	Medium	High
Soil	High	Medium	High
Water	High	Small	Medium
Use of natural resources	High	Medium	High
Landscape	Medium	Low Small	Very low
Cultural heritage	N/A	N/A	N/A

Social

As shown above, the implementation of these measures will ultimately help to reduce flood risk to downstream settlements which is considered to be a benefit.

³ Forestry Commission (2011), *Forests and Water*. UK Forestry Standard Guidelines. Forestry Commission, Edinburgh. I –iv + 1-80 pp

There is potential to enhance community engagement and improve recreation and tourism if NFM measures can be incorporated into the Forestry Commissions tourism strategy. This could include notice boards or walks which details the measures and how they contribute to flood alleviation.

It is understood that there exists the public perception that Scottish Power (as operators of the hydropower schemes) and the Forestry Commission (through their extensive forest operations) may be exacerbating flood risk to downstream communities. The implementation of the NFM measures, particularly if the communities are engaged with Scottish Power and the Forestry Commission in this, has the potential to enhance the understanding of the roles these parties play in mitigating and managing flood waters.

Overall it is considered there would be a social benefit associated with the implementation of the NFM measures.

8.2.4. New Galloway Runoff Reduction

This option includes:

- Land and soil management practices (catchment 31) – e.g. hedgerows (due to presence of defined field boundaries).
- Riparian woodland (catchment 31).

Feasibility / Engineering

The proposed options would be primarily located in the upper reaches of the catchment and as such it is not anticipated there would be any issues with the implementation of future flood mitigation works. Any future flood mitigation works would likely be focused on the immediate environs to the village of New Galloway, aimed at protecting individual properties and businesses. The provision of flood attenuation areas upstream of settlements are frequently considered when assessing flood mitigation. However, it is considered any future flood attenuation area located in the upstream catchment of New Galloway would not be impacted by the proposed measures.

The planting of hedges and riparian woodland could take several years to reach maturity and the benefits for runoff reduction to be realised.

It is anticipated that the runoff reduction measures could be implemented within a reasonable short timeframe of around 12 to 18 months depending on seasonal circumstances. The planting of hedge rows and riparian woodland should be implemented to suit their optimum planting time. These factors may extend the overall timescales for implementation towards 18 months.

The anticipated costs to install the proposed measures are presented in the table below. Please note that for Riparian Woodland SEPA NFM guidance is for a 30 m buffer however for practical implementation at this stage of the costings we have assumed a 15 m buffer to account for topography and landowner discussions.

Table 8.23: New Galloway Runoff Reduction Cost Estimate

NFM Measures	Dimensions	Estimated Cost	Total Cost
Hedgerow Planting	9 km (based on mapped field boundaries all being suitable and landowner agreements)	£5 / m	£45,000
Stock Proof Fencing	18 km – Based on each side being fenced	£4 / m stock fencing	£72,000
Riparian woodland	(based on 15 m buffer either side of watercourse) = 6.9 ha	£4,000 / ha	£27,600
Option Total			£144,600

Overall the estimated cost is £144,600 which, in accordance with

Table 8.3, the project cost rank is

considered to be Low. Once implemented it is considered maintenance costs would be low. Generally, the measures should be left to grow and mature on their own with little or no maintenance required. Hedgerows may need regular trimming depending on their location but it is anticipated that once planted they could generally be left to grow unattended.

The main health and safety risks which will need to be managed are considered to include:

- Some remote working in an upland environment.
- Working adjacent to watercourses which have the potential to be located in areas of steep terrain and unstable ground.

Land Management

Landowner engagement will be required to determine the feasibility of this project.

Hydrological

The results and benefit outcome of the hydrological assessment are summarised in Table 8.24 below.

Table 8.24: New Galloway Runoff Reduction Hydrological Results

Description	Compliance Point	% Reduction in Flow for Return Period				Benefit Outcome
		1 in 2	1 in 10	1 in 50	1 in 200	
New Galloway	Carsphairn	0	0	0	0	N/A
	Dalry Floodplain	0	0	0	0	N/A
Runoff Reduction	New Galloway	7.8	6.6	4.6	4.1	Low
	Clatteringshaws Loch	0	0	0	0	N/A
	Castle Douglas	0.1	0.1	0	0	Negligible
	Kirkcudbright	0.1	0.1	0	0	Negligible

Environmental

Runoff reduction measures can provide a number of environmental benefits, however it is acknowledged that the realisation of these benefits can be spatially and temporally dependent upon the scale of implementation of specific measures.

The consideration of NFM woodland planting as well as hedgerows has the potential to provide a positive impact via a reduction in the erosion of soils from watercourse banks as well as through overland sheet flow.

The NFM measures are unlikely to change the WFD status of the overall catchments due to the existing and potential future catchment pressures as well as the spatial extent of measures considered. However, implementation of NFM has the potential to provide improvements to tributary catchments at a local scale. There are no proposals to reduce existing structures on watercourses or alter existing hydropower operations.

Landscape was classed as Medium due to the presence of the Regional Scenic Area, the effects of the measures are localised therefore benefits in terms of landscape character are very low. It is considered hedgerow and riparian planting could benefit the landscape character in the local area therefore localised effects could be higher than the regional perspective assessed in this report*.

None of the measures will directly impact any designated cultural heritage interests (ref section 5.1.6). Any non-inventory interests would be assessed in the detailed design and the NFM measures micro-sited to avoid significant impacts.

A summary of the benefits on environmental receptors is presented in Table 8.25.

Table 8.25: Summary of Environmental Benefits (Carsphairn River Reach and Floodplain Storage)

Environmental Receptor	Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome
Flora and Fauna	High	Small	Medium
Soil	Low	Small	Very Low
Water	High	Small	Moderate
Use of natural resources	High	Medium	High
Landscape	Medium	Low Small	Very low*
Cultural heritage	N/A	N/A	N/A

Social

Whilst the scale of these measures are limited in terms of flood reduction, their implementation will benefit through improvements in biodiversity that will create a better connection to the environment and improve landscape character, giving a greater sense of place.

It may also be possible to incorporate recreational activities into the measures or assist learning and development for schools and other interested groups keen to understand the measures, their benefits, and their long term evolution.

Overall it is considered there would be a social benefit associated with the implementation of the NFM measures.

8.3. Proposed NFM Options

The Assessment Forms in Appendix C, enabled a detailed comparison of the NFM measures to be undertaken and a ranking of potential NFM measures to be determined. A summary of the assessment and resulting ranking of potential NFM options is included in Table 8.26 below. Figures GB11820_M_013 through to GB11820_M_016 (Appendix D) illustrate the potential location of the NFM measures within each catchment.

Table 8.26: Proposed NFM Options and Ranking

NFM Action	Future Adaptation	Timescale Realisation	Works	Cost Delivery	Maintenance	Hydrological Benefit		Environmental Benefit		Social Benefit	Rank
Carsphairn - Runoff Reduction	No foreseeable issues with future flood mitigation proposals	2 years plus	12 to 18 months	Medium	Low	Carsphairn	Very High	Flora & Fauna	High	1) Reduced flood risk.	1
						Dalry Floodplain	Low	Soil	Moderate	2) Enhanced community engagement.	
						New Galloway	Low	Water	High	3) Increased biodiversity.	
						Clatteringshaws Loch	N/A	Use of Natural Resources	High		
						Castle Douglas	Low				
						Kirkcudbright	Low	Landscape	Very Low		
Carsphairn - River Reach & Floodplain Storage	No foreseeable issues with future flood mitigation proposals	12 to 18 months	6 to 12 months	High	Low	Carsphairn	High	Flora & Fauna	High	1) Reduced flood risk.	2
						Dalry Floodplain	Very Low	Soil	Moderate	2) Enhanced community engagement.	
						New Galloway	Very Low	Water	Very Low	3) Increased biodiversity.	
						Clatteringshaws Loch	N/A	Use of Natural Resources	High		
						Castle Douglas	Negligible				
						Kirkcudbright	Negligible	Landscape	Very Low		
Clatteringshaws - Runoff Reduction	No foreseeable issues with future flood mitigation proposals	2 years plus	2 years plus	Low	Low	Carsphairn	N/A	Flora & Fauna	High	1) Reduced flood risk.	3
						Dalry Floodplain	N/A	Soil	High	2) Enhanced community engagement.	
						New Galloway	N/A	Water	Medium	3) Increased biodiversity.	
						Clatteringshaws Loch	High	Use of Natural Resources	High	4) Improved relations between local community	
						Castle Douglas	Low				
						Kirkcudbright	Low	Landscape	Very Low		

NFM Action	Future Adaptation	Timescale Realisation	Works	Cost Delivery	Maintenance	Hydrological Benefit		Environmental Benefit		Social Benefit	Rank
New Galloway - Runoff Reduction	No foreseeable issues with future flood mitigation proposals	2 years plus	12 to 18 months	Low	Low	Carsphairn	N/A	Flora & Fauna	Medium	and Forestry Commission. 1) Reduced flood risk.	4
						Dalry Floodplain	N/A	Soil	Very Low	2) Enhanced community engagement.	
						New Galloway	Low	Water	Moderate	3) Increased biodiversity.	
						Clatteringshaws Loch	N/A	Use of Natural Resources	High		
						Castle Douglas	Negligible				
						Kirkcudbright	Negligible	Landscape	Very Low		

9. Landowner and Stakeholder Engagement

The proposed NFM measures were presented at a series of meetings with key stakeholders. This was an opportunity to open dialogue on the assessment approach and the measures proposed in order to gather feedback that could be used to optimise the strategy and finalise the options shortlist. The meetings arranged are detailed below.

SEPA & DGC Flood Team– Natural Power, together with the Galloway Glens project team, attended a meeting with SEPA and Dumfries and Galloway Council Flood Department on the 28th March 2017 at Castle Douglas Town Hall. The project team outlined the methodology and modelling undertaken to arrive at an initial short list of options for the Dee Catchment. There was broad acceptance of the approach and that subject to reviewing the more detailed assessment reports for Carsphairn the project should progress towards engaging landowners and the community in the project.

Landowners - A meeting was held with landowners on the 13th March 2017 at Carsphairn Town Hall. This was attended by Andy Precious and McNabb Laurie. The approach to the project was outlined with a list of potential natural flood management options presented for consideration. This included images of each of the potential options used on similar schemes as a visual aid. It was made clear that all the options were in the feasibility stage and that Galloway Glens is not a statutory consultee with no powers to enforce the measures. There was discussion on the wider landuse within the study area and how this may affect flooding in the area. No objections were raised specifically to this study and its aims.

Subsequent to this meeting landowners were contacted via email to agree access to undertake site surveys. Where contact could not be made visual surveys were undertaken from the road side.

Carsphairn Community Councils - A similar presentation was delivered to the Carsphairn Community Council on the 27th March 2017 as part of their monthly community meetings. The presentation was slightly condensed in order to meet the 15 minutes allocated on the agenda but there was sufficient time to answer questions and gather feedback on the project.

10. Next Steps and Progression

Natural Power have undertaken an assessment of NFM opportunities on the River Dee catchment and identified and reviewed a short list of NFM measures that would provide hydrological, environmental and social benefits.

An initial Option Appraisal has been undertaken to assess the merits of the short list options and determine a prioritised list of NFM measures. The prioritised list of options is summarised in the table below.

Table 10.1: Identified NFM Priority Options

Option	Priority Ranking
Carsphairn Runoff Reduction	1
Carsphairn River Reach and Floodplain Storage	2
Clatteringshaws Runoff Reduction	3
New Galloway Runoff Reduction	4

The next stage of the project would be to build on the initial option appraisal to complete a full Option Appraisal.

Option Appraisal

The Option Appraisal should identify and review the various identified options in order to implement the prioritised measures and their relative advantages and disadvantages. The main objective is to provide sufficient information to reach agreement on a preferred option or options (in consultation with the landowner/land manager and other stakeholders) and to outline additional assessments/surveys required to progress the preferred options

This stage should be undertaken in consultation with the landowners and would require land registry searches to accurately map landowner boundaries prior to more detailed engagement on the measures being proposed and their micro siting. Other relevant stakeholders will also need to be consulted to reach agreement on a preferred option(s) and to outline additional assessments/surveys required to progress the preferred option.

The hydrological benefits presented in this report are based on the full implementation of the identified measures in the catchments. As the detail of the option(s) is further refined in consultation with the landowners there is the potential that the extent of the option(s) reduces from that presented in this study. Therefore, further modelling of the preferred option(s) should be undertaken to verify its hydrological benefits as the details of the option(s) become more defined. The hydrological benefits gained from the implementation of NFM measures depend on several factors including the nature of the individual catchment, the location and extent of the NFM measure within the individual catchments, the catchments influence in the overall hydrological process and the influence of varying the timing of catchment peak flows on the overall hydrological process. However, as a crude approximation for informing landowner discussions on the option(s) it could be assumed that a percentage reduction in the option(s) implemented area would have a similar percentage reduction in the flow reduction (e.g. if 100% option implementation is predicted to provide a 14% reduction in flow, then 50% option implementation could be assumed to provide a 7% reduction in flow).

The option appraisal stage should review the prioritised options and if appropriate consider partial implementation of some options or elements from each of the identified options.

The final outputs of an options appraisal should build on this present study and include:

- Options Appraisal report detailing each option considered and associated costs and benefits;
- specification for the preferred option(s); and
- estimated costs.

The Options Appraisal should identify project risks and develop corresponding risk mitigation strategies to be adopted.

Funding and sources of funding will be a key constraint to any option and should be considered as part of the Option Appraisal stage.

Once a preferred option is agreed upon, it can be taken forward to outline design and implementation.

Outline Design

Once a preferred option has been selected, outline designs should be developed that can be discussed between all the relevant parties, prior to committing to detailed design. The outline design should include technical drawings showing the scope and extent of the works, materials to be used, and reinstatement procedures. It should also include non-technical drawings, sketches or visualisations to indicate clearly what the site will look like once measures are in place in order facilitate discussions. The outline design should be gradually amended until the landowner/ land manager, funder and the regulatory/ planning authorities agree the design.

Detailed Design

Detailed design should contain all the information required to obtain the necessary consents and to guide construction of works on the ground. It should be informed by a number of surveys and assessments which will typically include:

- flood risk assessment informed by appropriate modelling;
- hydromorphological assessment (e.g. to inform analysis of river dynamics in a river channel prior to, and after, restoration).

All assessments should be informed by the necessary surveys. Information should also be gathered on potential ecological interests which could be impacted by the proposed measures or whose presence could impact the timing of groundworks.

The final outputs of the detailed design process should include:

- engineering drawings;
- non-technical drawings, sketches or visualisations;
- details of all the surveys and assessments undertaken;
- information on approach to modelling and modelling outputs;
- details of all consents;
- construction method statements; and
- recommendations for maintenance and management.

Implementation

The implementation stage should consider:

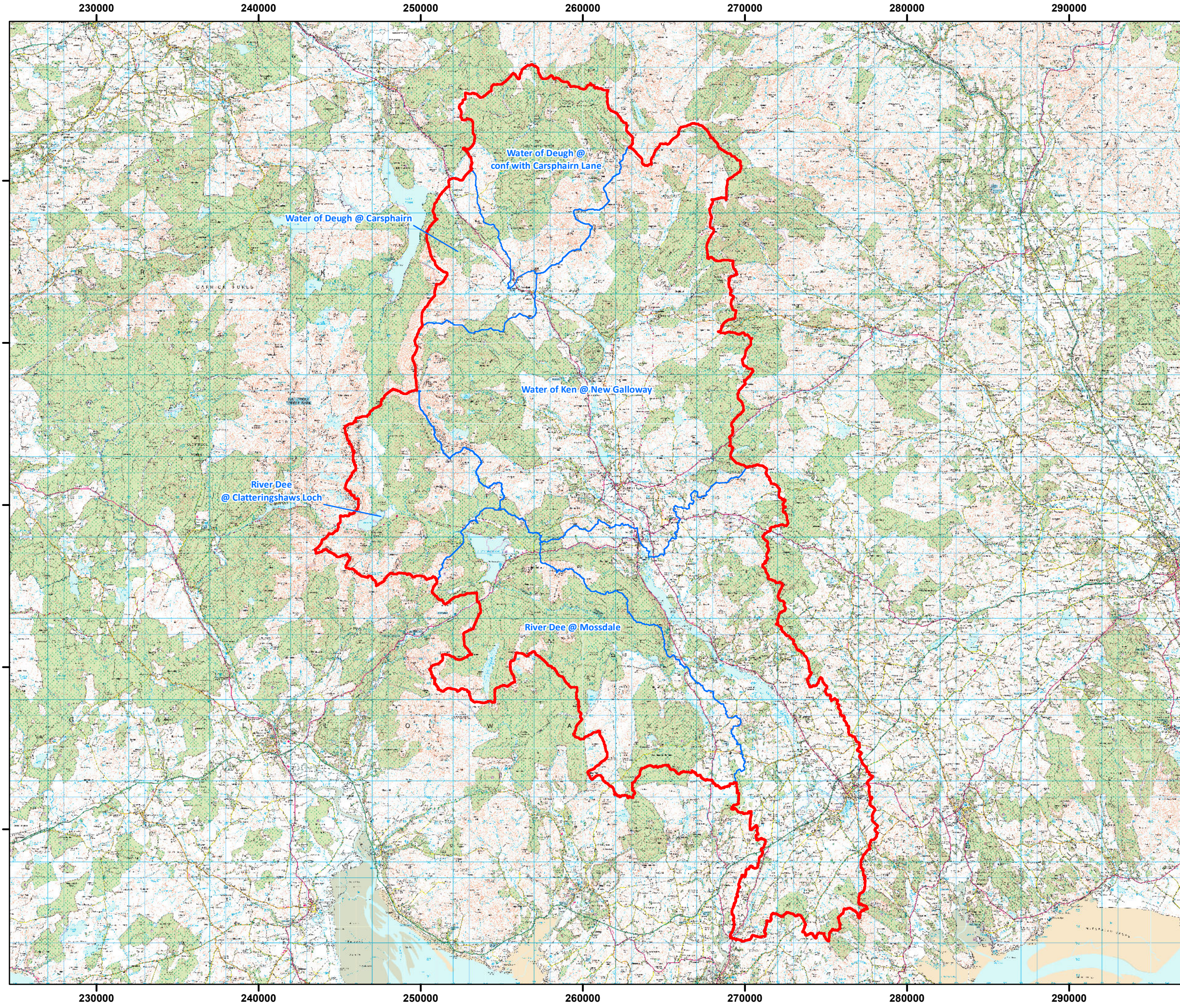
- Timing of Works (to minimise the environmental impacts of the works, preferences for growing seasons, etc).
- Staff resources (consideration of how to install the works using contractors, land managers, etc).
- Legal considerations (contractual arrangement, landowner agreements, etc).

Long Term Management and Monitoring

The long-term management and maintenance of the site will need to be agreed with the landowner/land manager on whose land the NFM measure has been implemented. The nature of the management agreement will be dependent on the financial mechanisms being used to deliver the measure.

Appendix A – Catchment Characterisation





Project:
**Galloway Glens
Natural Flood Management**

Title:
River Dee Catchment Area

Key

 River Dee Catchment Outline

 Secondary Catchment Outlines

DRAFT A1

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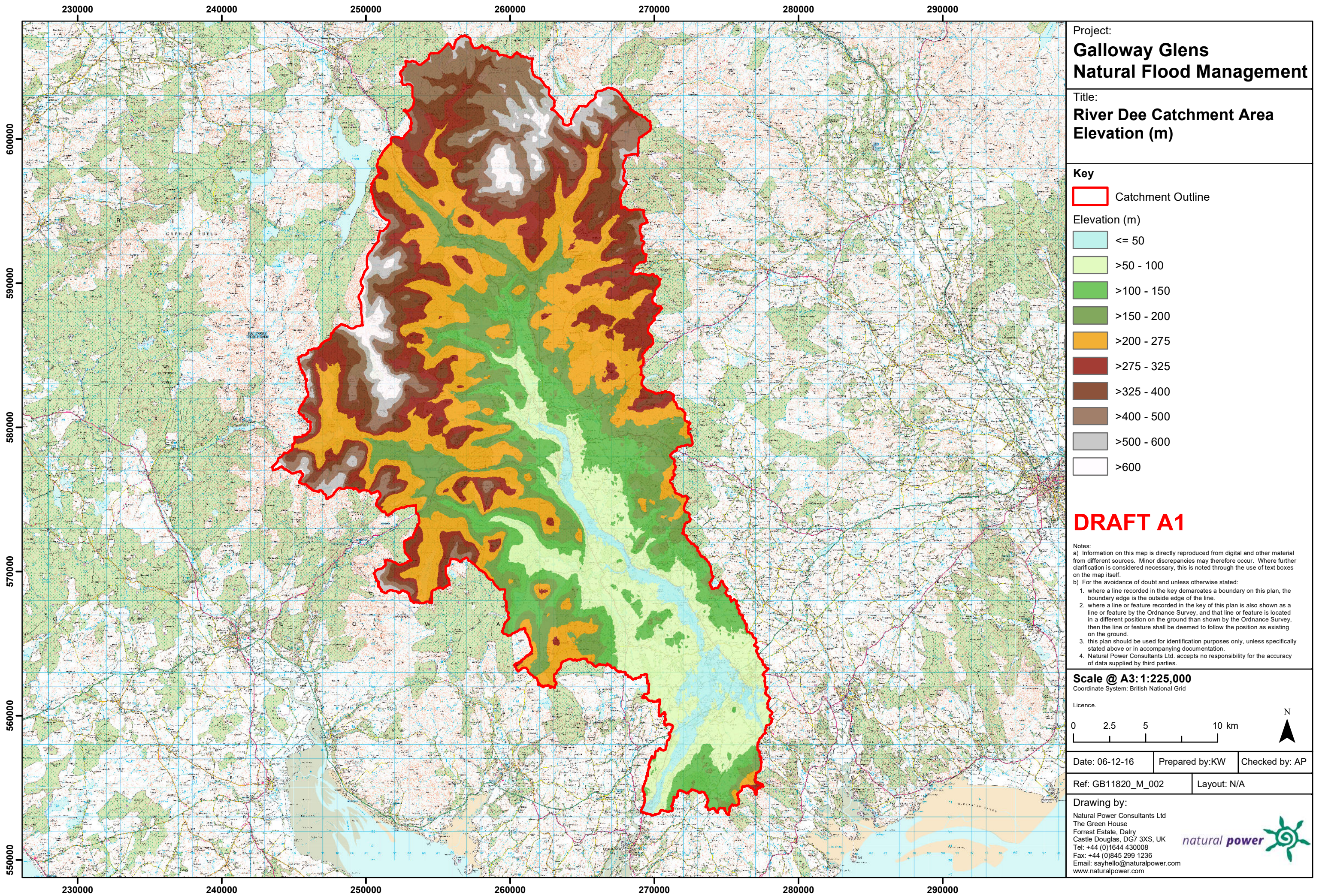
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Project:
**Galloway Glens
Natural Flood Management**

Title:
**River Dee Catchment Area
Elevation (m)**

Key

 Catchment Outline

Elevation (m)

	<= 50
	>50 - 100
	>100 - 150
	>150 - 200
	>200 - 275
	>275 - 325
	>325 - 400
	>400 - 500
	>500 - 600
	>600

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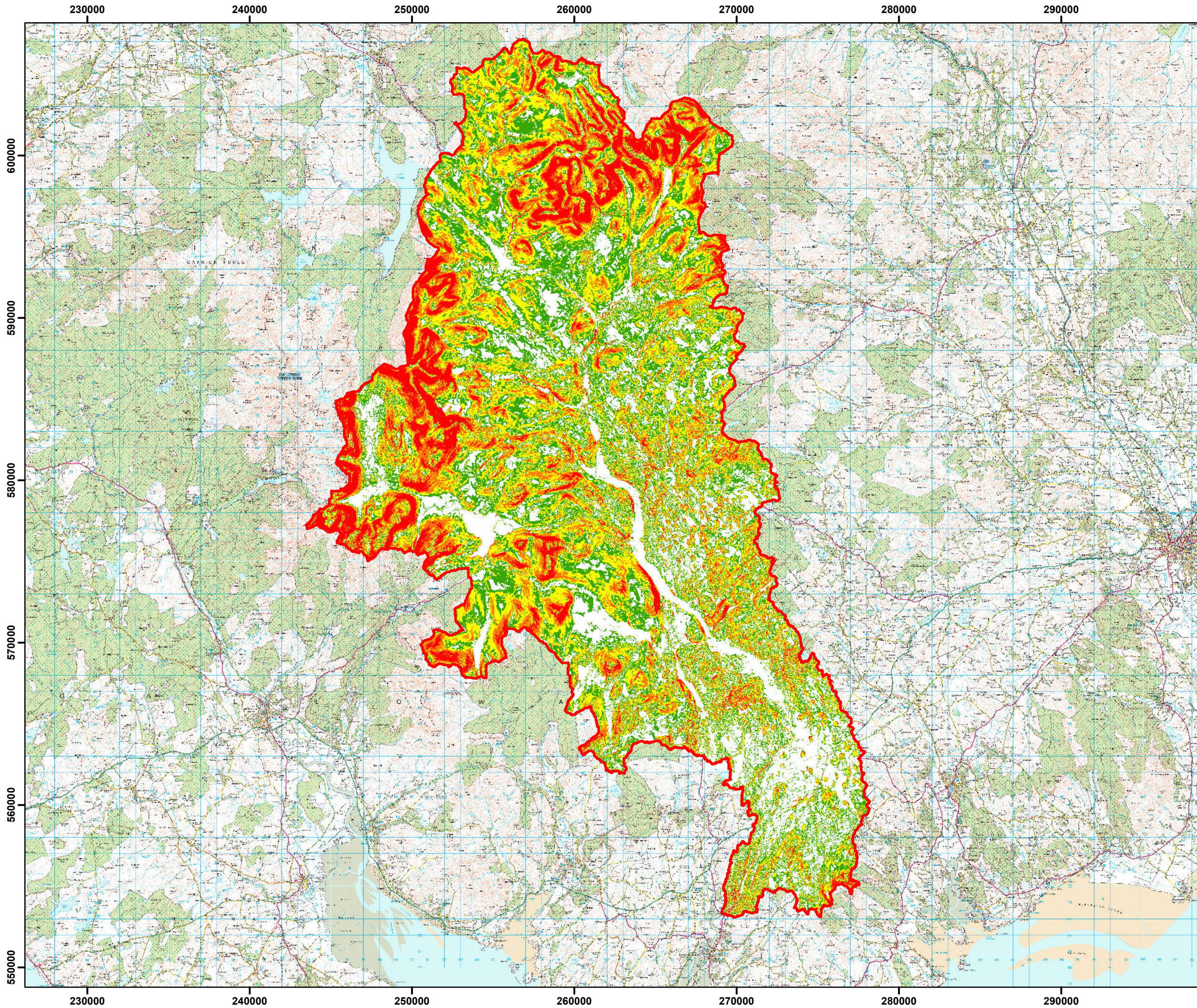
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Project:
**Galloway Glens
Natural Flood Management**

Title:
**River Dee Catchment Area
Slope (Degrees)**

Key

Catchment Outline

Slope (Degrees)

0 - 3

>3 - 6

>6 - 10

>10 - 15

>15

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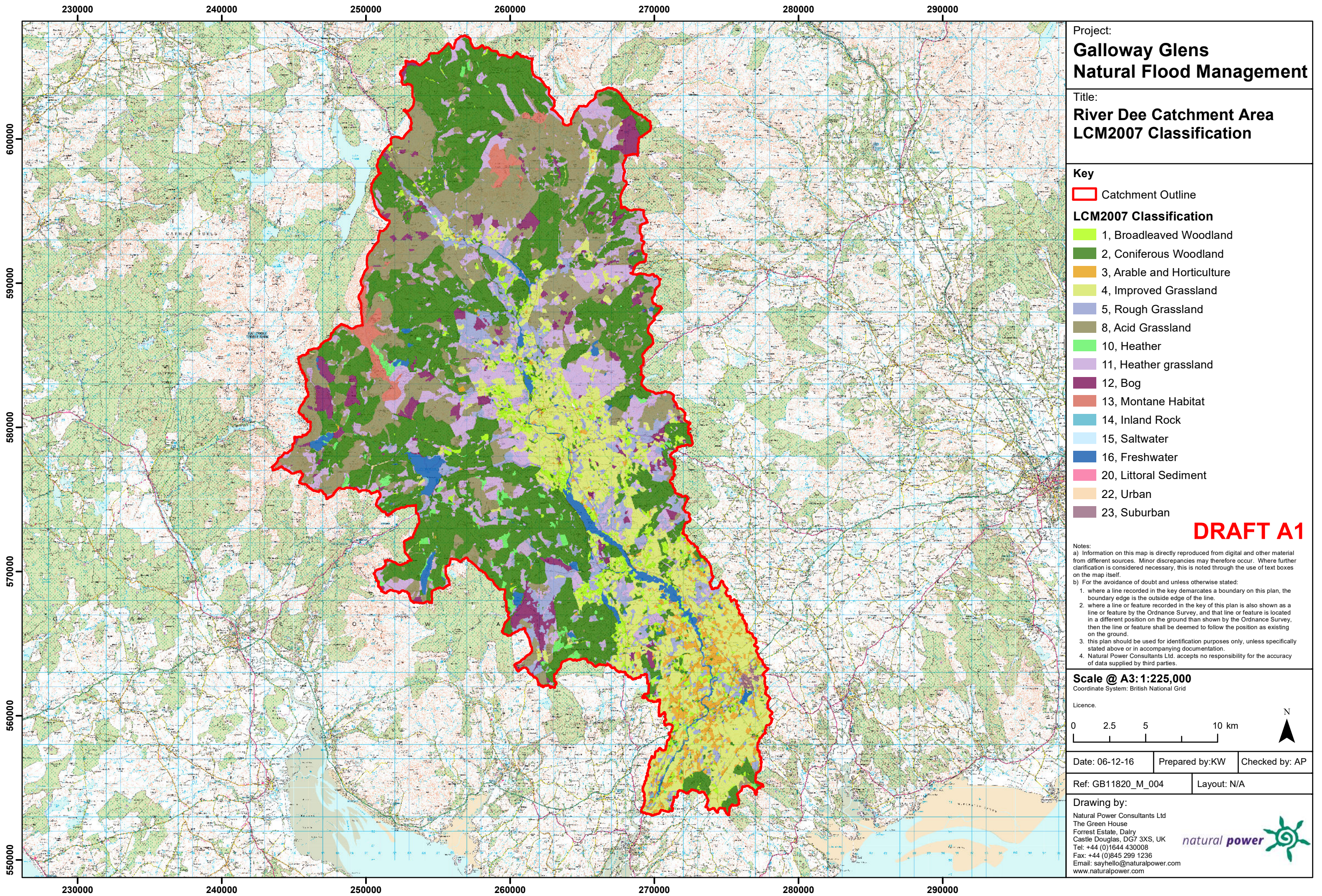
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Project:
**Galloway Glens
Natural Flood Management**

Title:
**River Dee Catchment Area
LCM2007 Classification**

- Key**
- Catchment Outline
- LCM2007 Classification**
- 1, Broadleaved Woodland
 - 2, Coniferous Woodland
 - 3, Arable and Horticulture
 - 4, Improved Grassland
 - 5, Rough Grassland
 - 8, Acid Grassland
 - 10, Heather
 - 11, Heather grassland
 - 12, Bog
 - 13, Montane Habitat
 - 14, Inland Rock
 - 15, Saltwater
 - 16, Freshwater
 - 20, Littoral Sediment
 - 22, Urban
 - 23, Suburban

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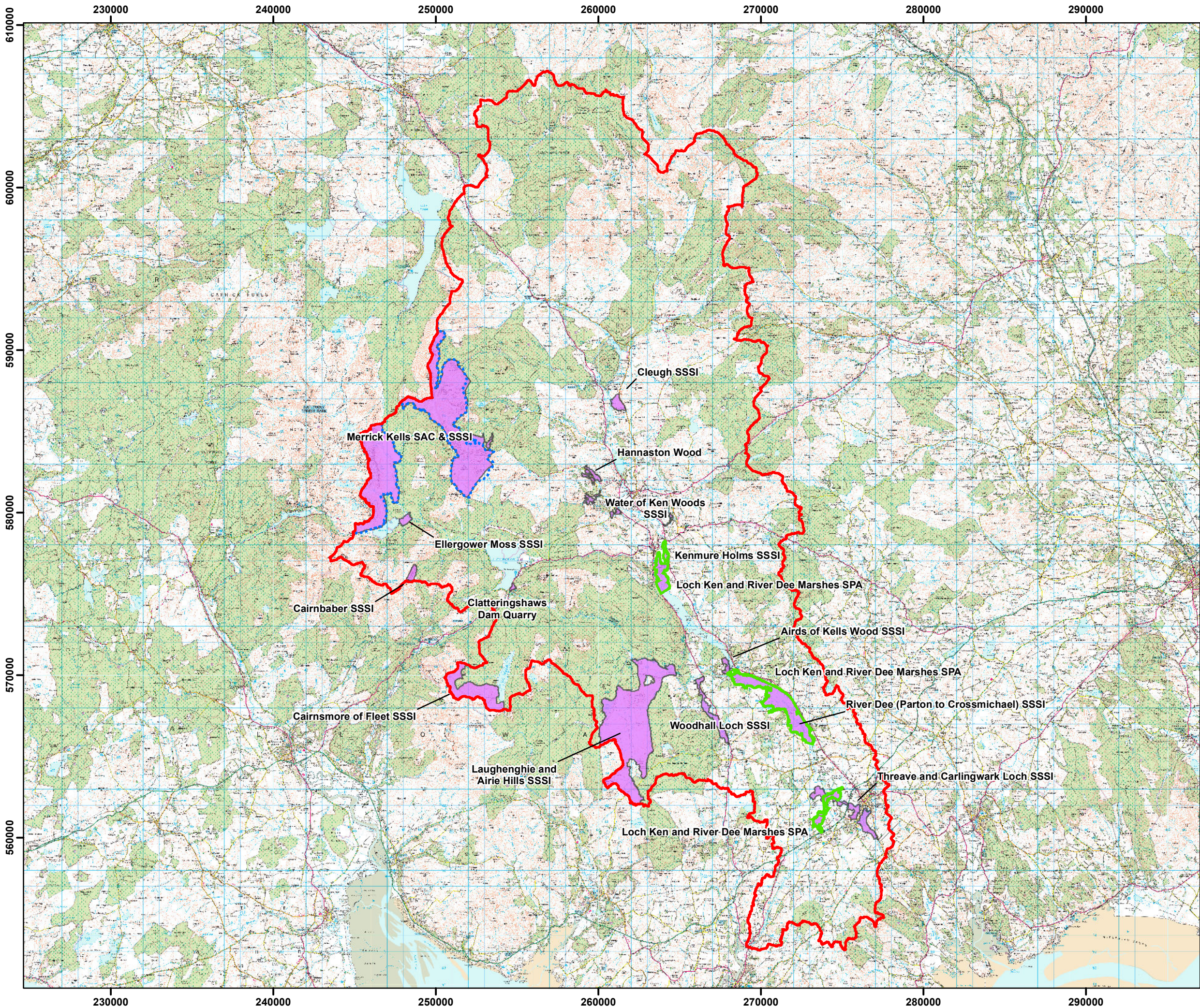
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Project:
**Galloway Glens
Natural Flood Management**

Title:
Environmental Designations

- Key**
-  Catchment Outline
 -  Special Protected Area
 -  Special Area of Conservation
 -  Site of Special Scientific Interest

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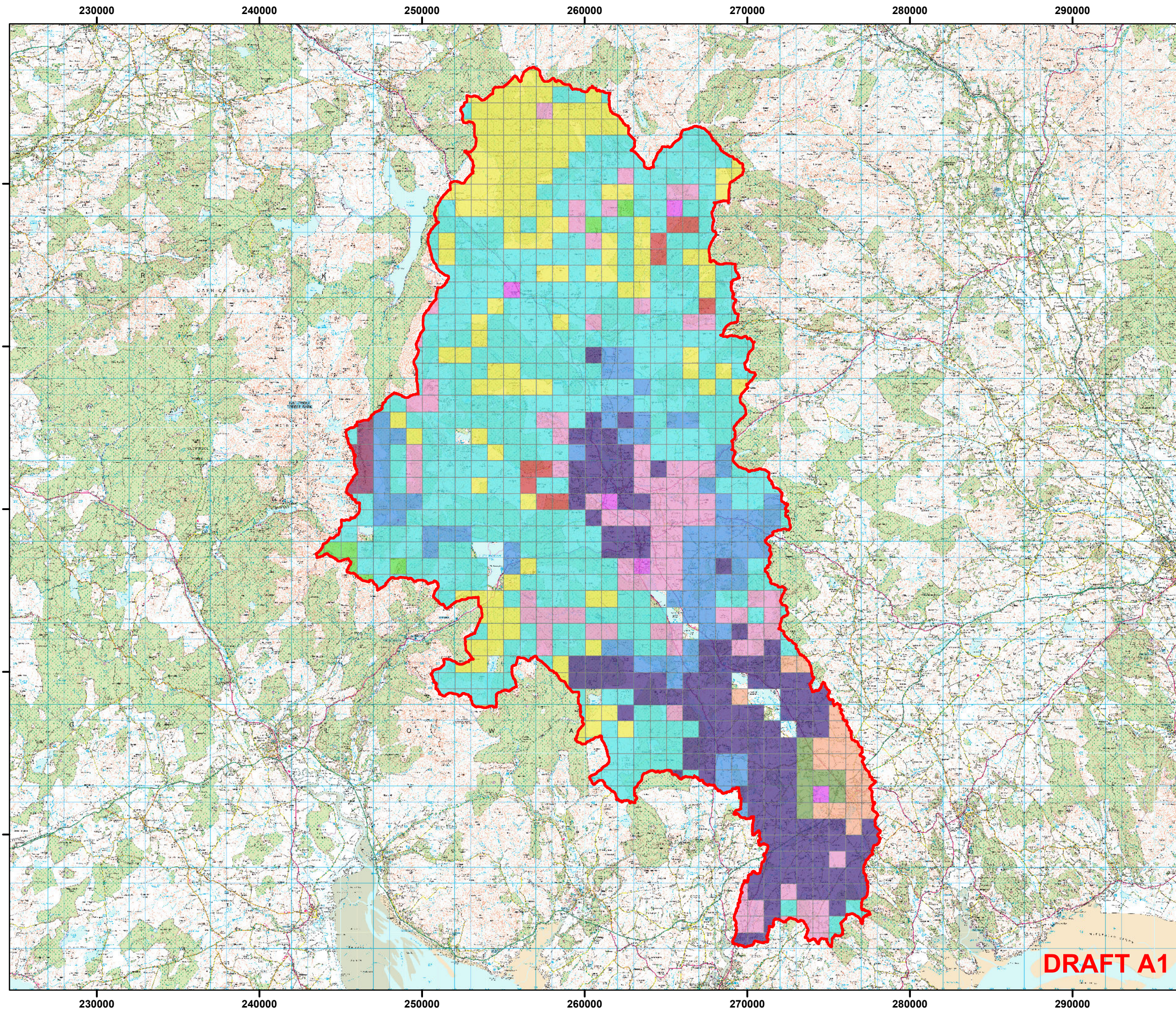


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Project:
Galloway Glens
Natural Flood Management

Title:
Predominant HOST Classification

- Key**
-  Catchment Outline
- Predominant HOST Classification**
-  HOST Class 5 Free draining permeable soils in unconsolidated sands or gravels with relatively high permeability and high storage capacity.
 -  HOST Class 7 Free draining permeable soils in unconsolidated sands or gravels with groundwater at less than 2m from the surface.
 -  HOST Class 12 Undrained lowland peaty soils waterlogged by groundwater.
 -  HOST Class 14 Soils seasonally waterlogged by perched water tables caused by impermeable subsoil or substrate layers.
 -  HOST Class 15 Permanently wet, peaty topped upland soils over relatively free draining permeable rocks.
 -  HOST Class 17 Relatively free draining soils with a large storage capacity over hard impermeable rocks with no storage capacity.
 -  HOST Class 19 Relatively free draining soils with a moderate storage capacity over hard impermeable rocks with no storage capacity.
 -  HOST Class 22 Relatively free draining soils with low storage capacity over hard impermeable rocks with no storage capacity.
 -  HOST Class 24 Slowly permeable, seasonally waterlogged soils over slowly permeable substrates with negligible storage capacity.
 -  HOST Class 27 Permanently wet, peaty topped upland soils over hard impermeable rocks with no storage capacity.
 -  HOST Class 29 Permanently wet upland blanket peat.

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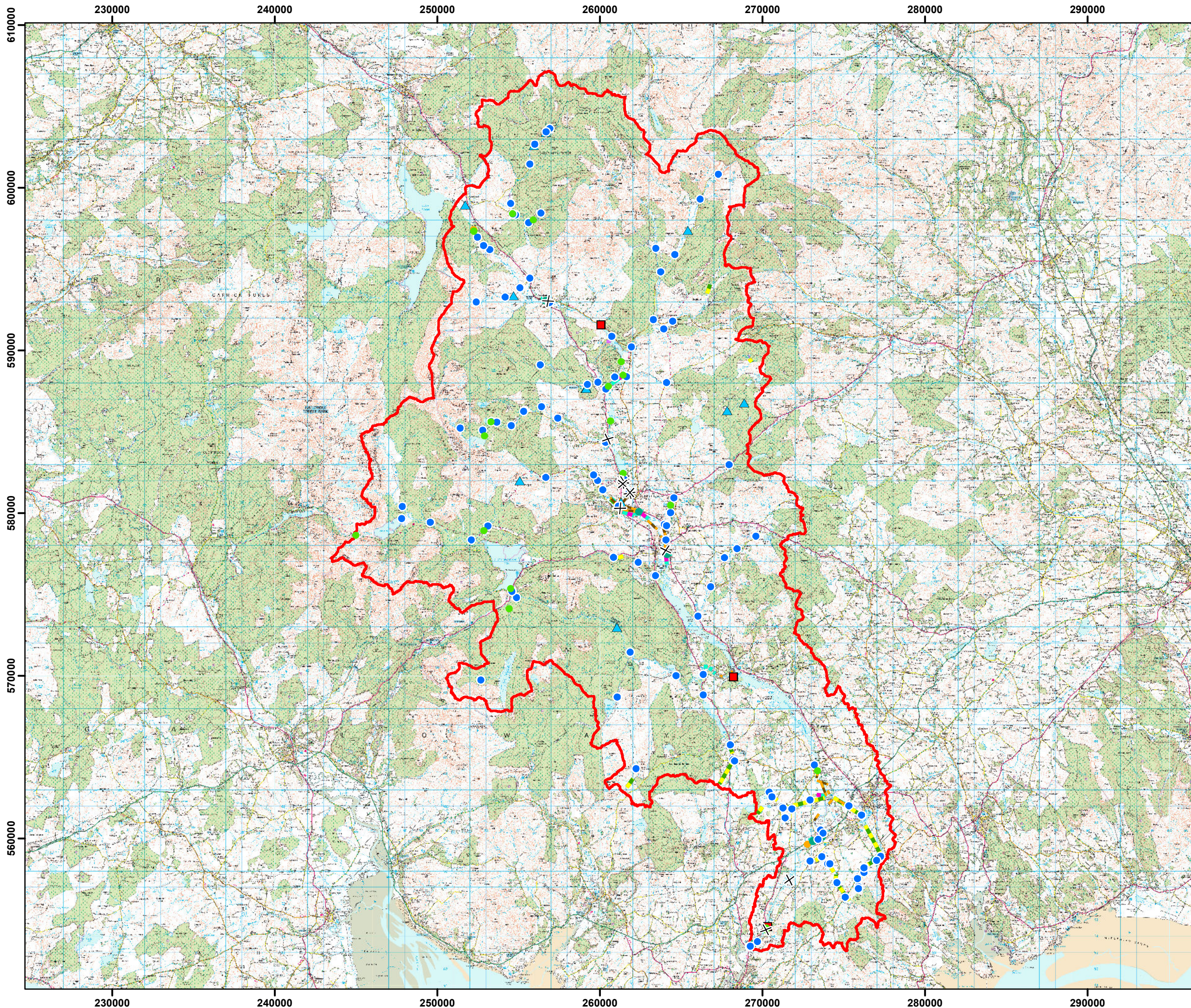
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Project:
**Galloway Glens
Natural Flood Management**

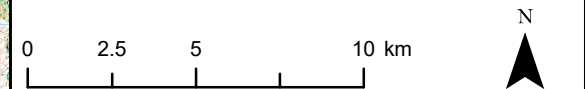
Title:
**SEPA Morphological
Pressures**

- Key**
- Catchment Outline
 - Impoundments
 - Bridges
 - Boatslips
 - Fords
 - Intakes and Outfalls
 - Pipe Cable Crossings
 - Embankments (No Reinforcement)
 - Hard Bank Reinforcement
 - Partial Realignment
 - Set Back Embankment
 - Green Bank Reinforcement

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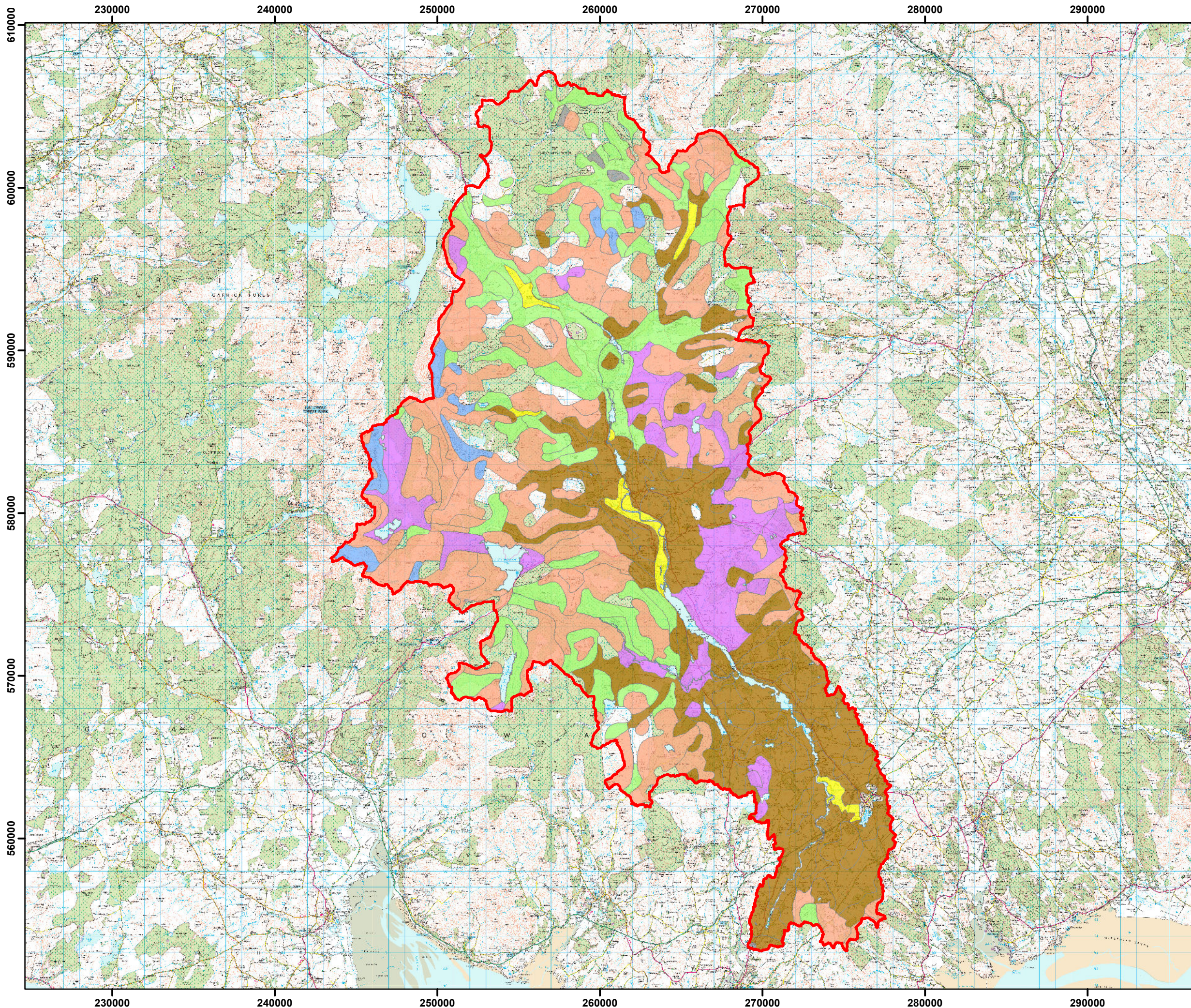
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Project:
**Galloway Glens
Natural Flood Management**

Title:
Soil Classification

Key

 Catchment Outline

Soil Classifications

 Alluvial soils

 Brown earths

 Ground-water gleys

 Peats

 Podzols

 Rankers

 Surface-water gleys

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0 2.5 5 10 km

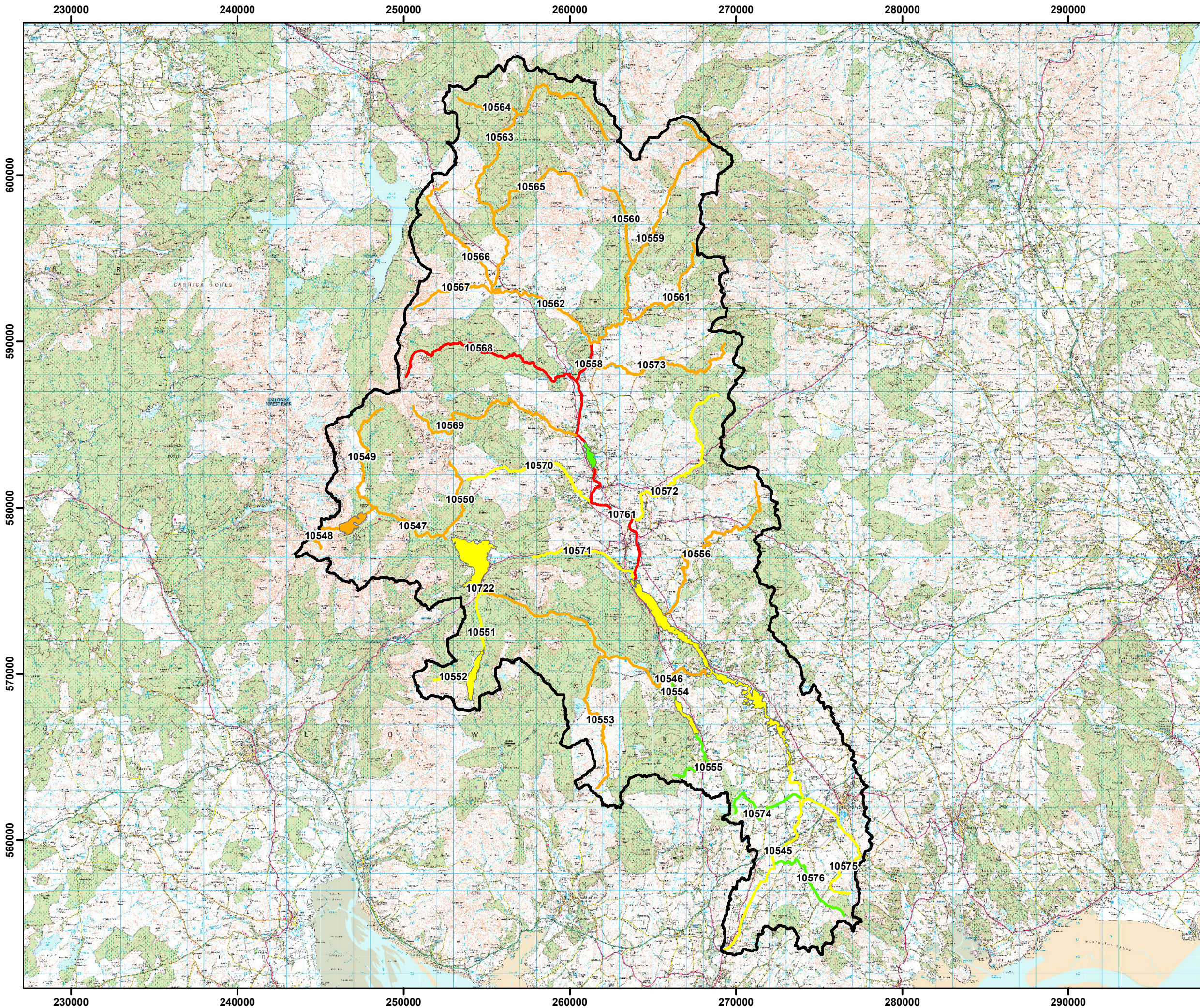
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Project:
**Galloway Glens
Natural Flood Management**

Title:
WFD RBMP Classification

Key

 Catchment Outline

RBMP 2015 River Classification

 Good status/potential

 Moderate status/potential

 Poor status/potential

 Bad status/potential

RBMP 2015 Waterbody Classification

 Good status/potential

 Moderate status/potential

 Poor status/potential

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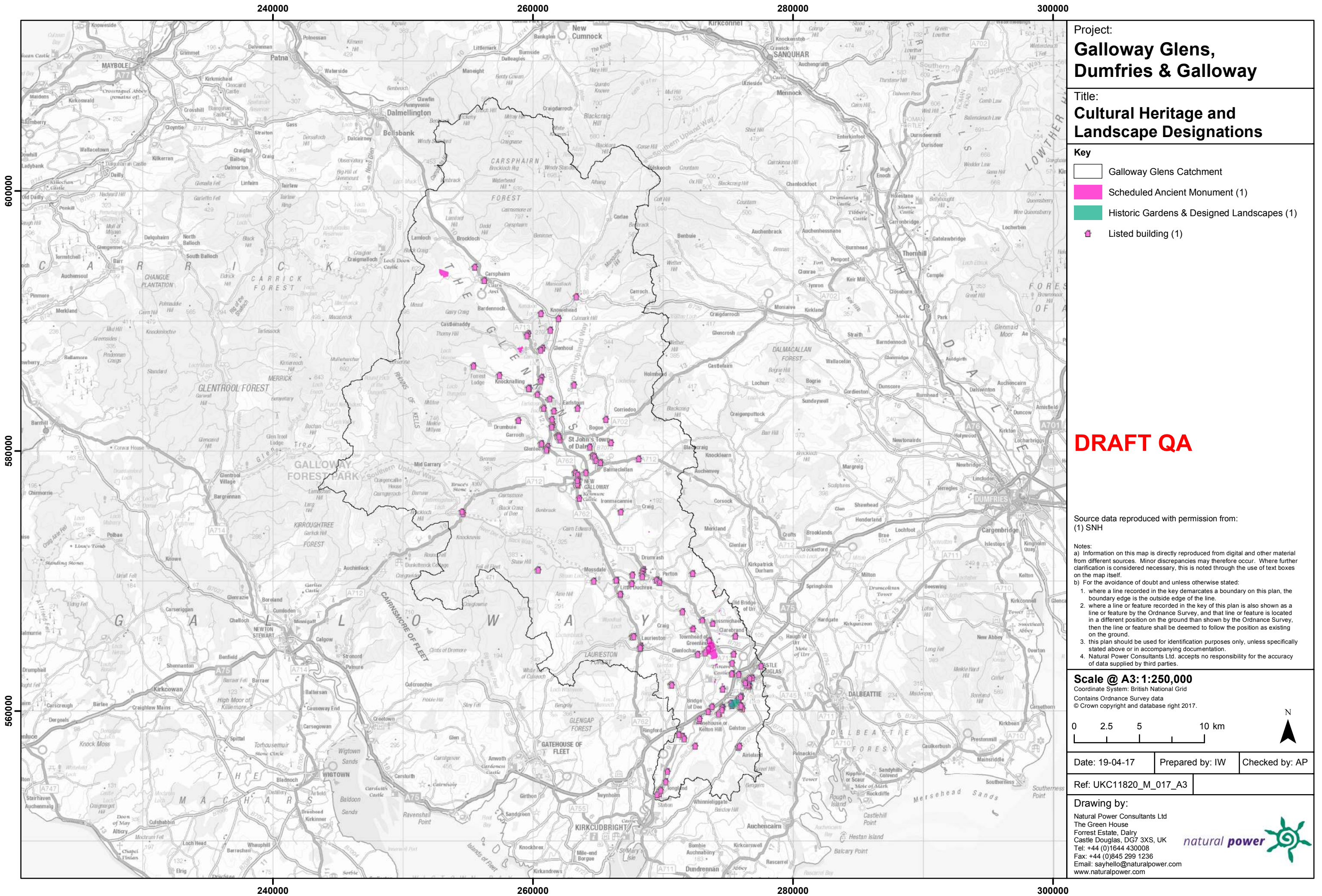
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Project:
**Galloway Glens,
Dumfries & Galloway**

Title:
**Cultural Heritage and
Landscape Designations**

- Key**
- Galloway Glens Catchment
 - Scheduled Ancient Monument (1)
 - Historic Gardens & Designed Landscapes (1)
 - Listed building (1)

DRAFT QA

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0 2.5 5 10 km

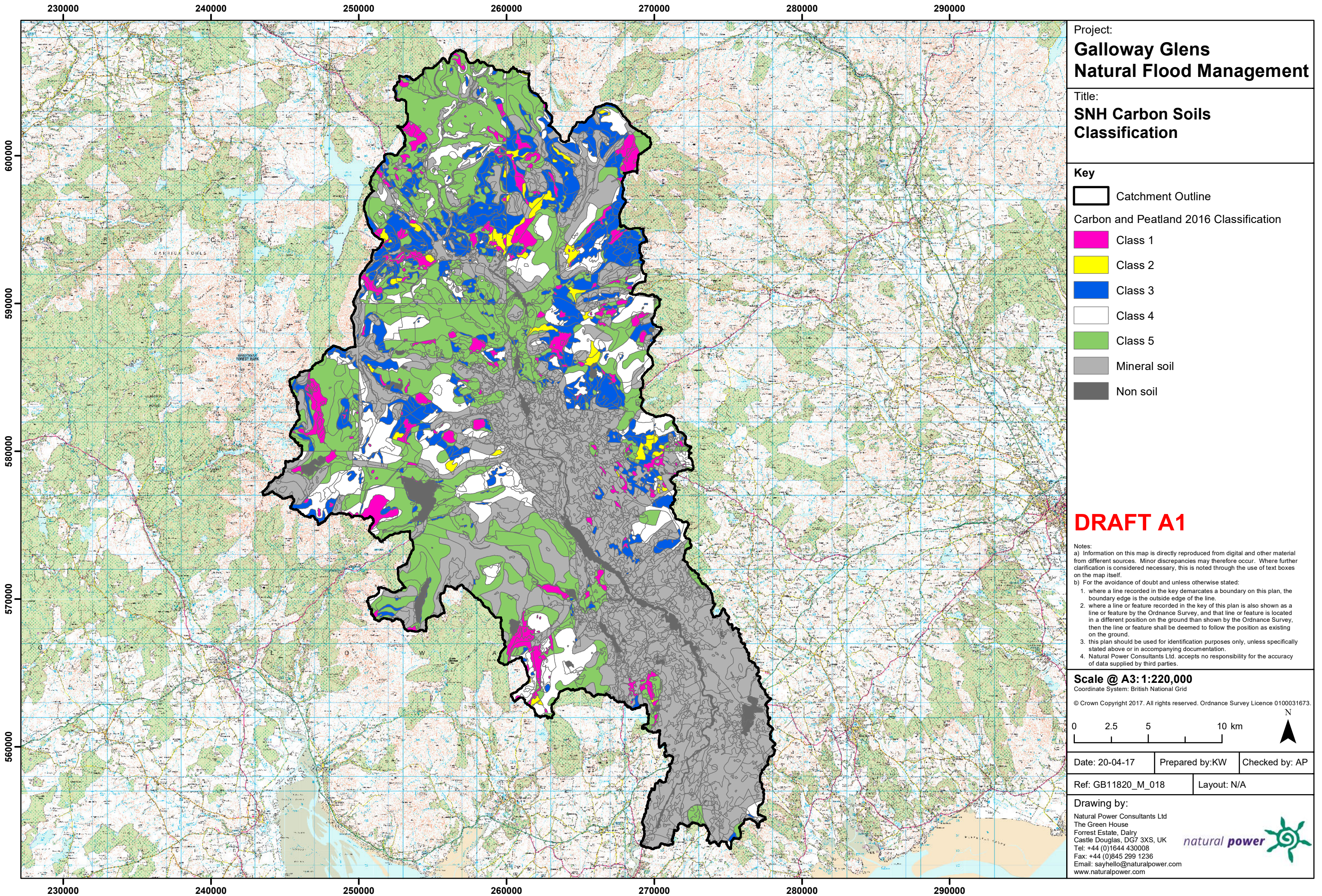
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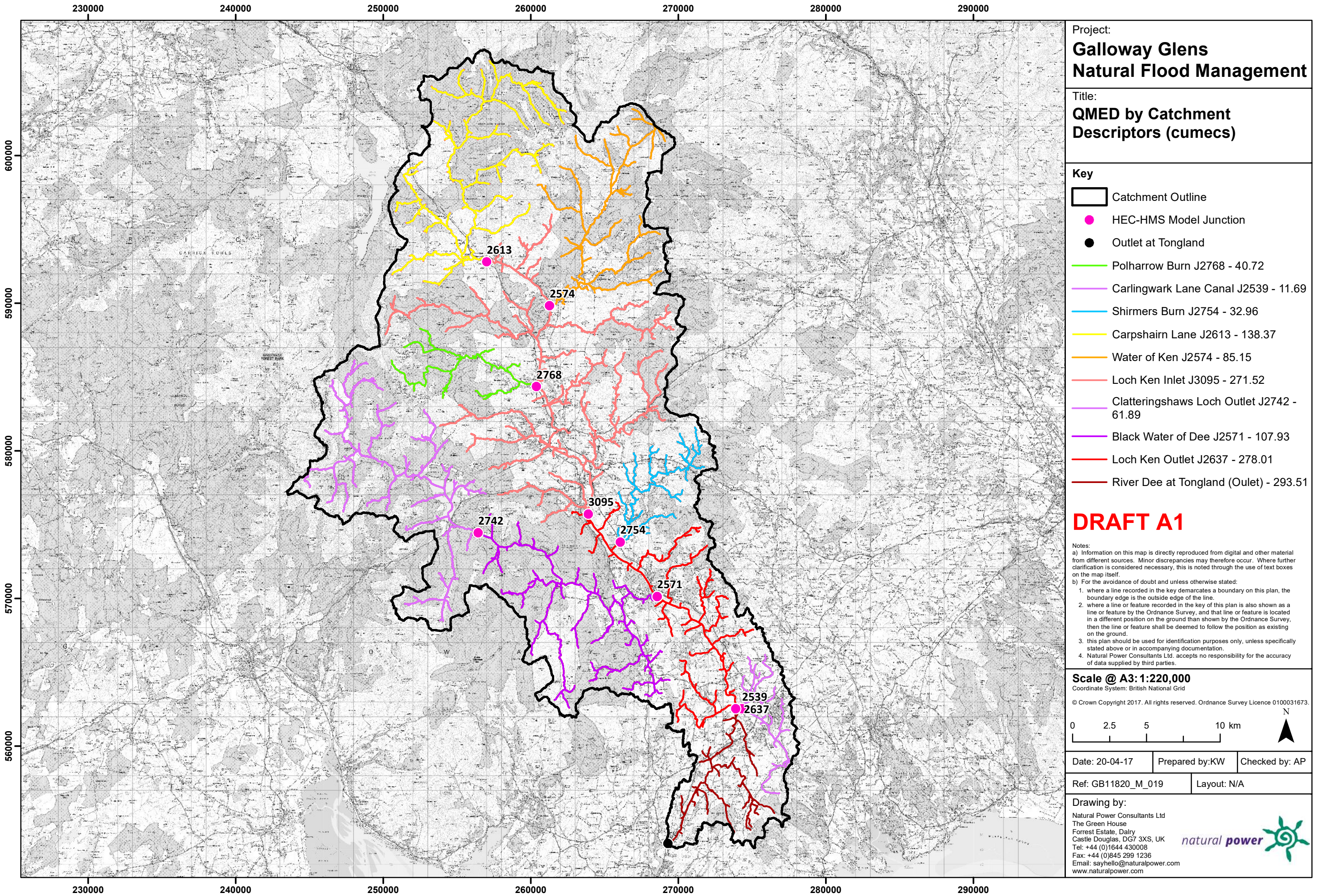
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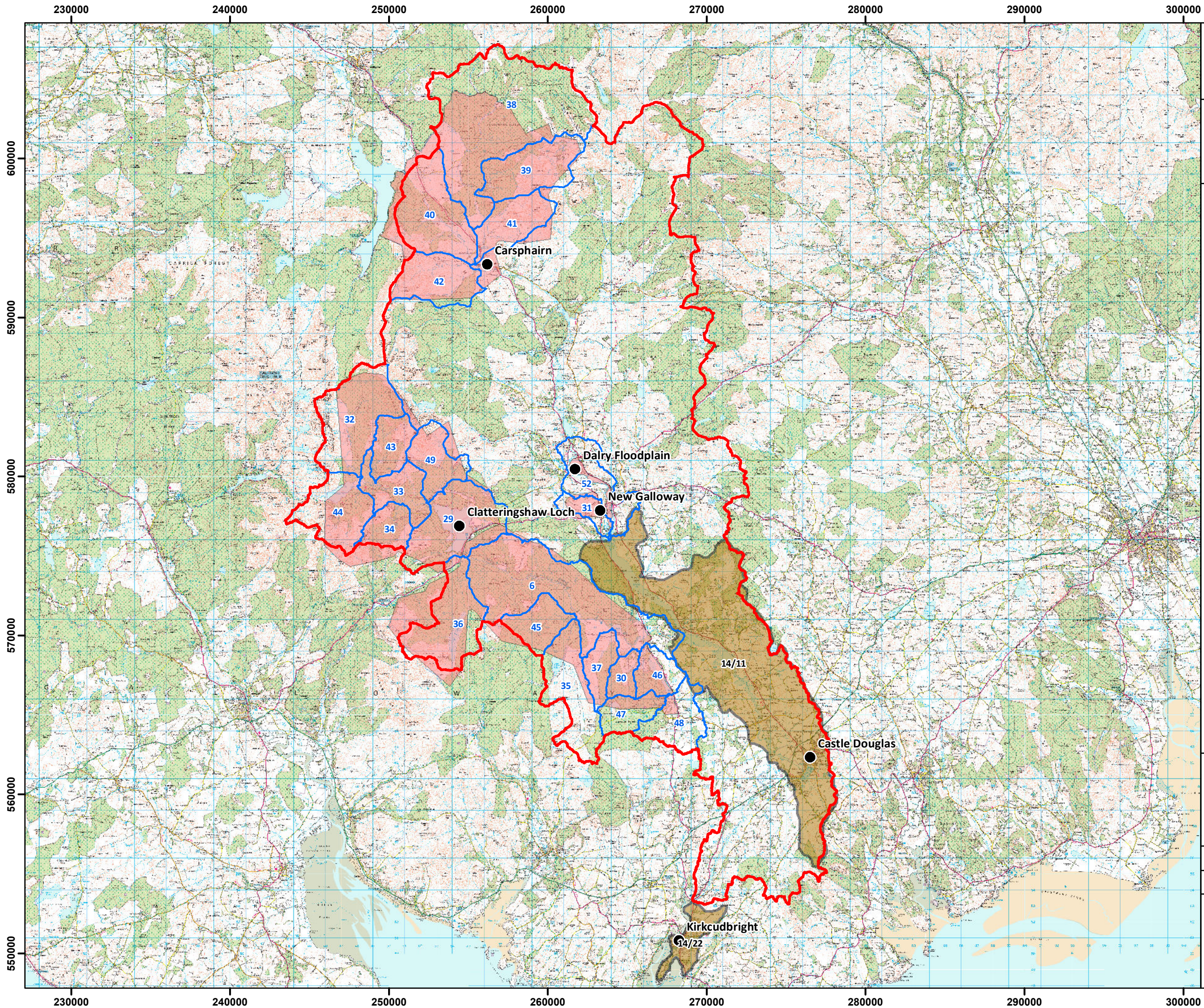






Appendix B – Long List Figures





Project:
**Galloway Glens
Natural Flood Management**

Title:
**Galloway Glens
Natural Flood Management
Long Listing Catchments**

- Key**
-  River Dee Catchment Outline
 -  Primary Receptors
 -  NFM Long Listing Catchments
 -  Study Priority Areas
 -  SEPA Potential Vulnerable Areas

DRAFT A1

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Appendix C – NFM Measures Assessment Forms



Long List Measures Not Taken Forward



Option:		New Galloway – Sediment Management						
Overview		Sediment Management NFM Measures in Catchments at New Galloway (31)			Measures considered include: ▪ River bank restoration; Catchment 31. ▪ Overland sediment traps; Catchment 31.			
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		Could potentially affect future flood prevention measures.						
NFM measure benefit realisation		2 yrs+						
Timescales of Works		6 – 12 months						
Estimated Cost to Deliver		High – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain. Likely require working within watercourses with associated H&S and environmental controls to manage construction works.						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment and within watercourses. Works have the potential to be located in areas of steep terrain (i.e. upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	Percentage reduction in flow considered insufficient to implement NFM measures and therefore options have not been considered further.
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
New Galloway	2.0	1.3	0.9	0.7	Medium	Small	Low	
Clatteringshaws	0.0	0.0	0.0	0.0	N/A	N/A	N/A	

Loch								
Castle Douglas	0.0	0.0	0.0	0.0	Very High	Negligible	Negligible	
Kirkcubright	0.0	0.0	0.0	0.0	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Social Benefit								
Option Summary								
Measures considered include: - River bank restoration; Catchment 31. - Overland sediment traps; Catchment 31.								
Progress Option to Short List					No			

Option: Clatteringshaws Loch – River Reach & Floodplain Storage								
Overview		River Reach and Floodplain Storage NFM Measures in Catchments at Clatteringshaws (29, 32, 33, 34, 43, 44 and 49)				Measures considered include: ▪ Instream Structures; Catchments 29, 32, 33, 34, 43, 44 & 49		
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		No foreseeable issues with future flood mitigation proposals						
NFM measure benefit realisation		Following installation						
Timescales of Works		6 months						
Estimated Cost to Deliver		Medium/High – works requiring contractors with plant / machinery working in remote locations with difficult access and terrain and working within watercourses.						
Maintenance costs		Medium						
Health & Safety		NFM measures will require remote working in upland environment and within watercourses. Works have the potential to be located in areas of steep terrain (i.e. adjacent to upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	Percentage reduction in flow considered insufficient to implement NFM measures and therefore options have not
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
New Galloway	0.0	0.0	0.0	0.0	N/A	N/A	N/A	

Clatteringshaws Loch	3.3	1.1	1.4	2.4	Medium	Very Small	Very Low	been considered further.
Castle Douglas	0.6	0.4	0.1	0.4	Very High	Negligible	Negligible	
Kirkcubright	0.6	0.3	0.2	0.3	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Flora and Fauna								
Soil								
Water								
Use of natural resources								
Landscape								
Cultural heritage								
Social Benefits								
Option Summary								
Measures considered include: ▪ Instream Structures on Catchments 29, 32, 33, 34, 43, 44 & 49. ▪								
Progress Option to Short List				No				

Option:	Clatteringshaws Loch – Sediment Management							
Overview	Sediment Management NFM Measures in Catchments at Clatteringshaws (29, 32, 33, 34, 43, 44 & 49)				Measures considered include: River bank restoration; Catchments 29, 32, 33, 34, 43, 44 & 49.			
Feasibility Issues	Landowner acceptance Funding							
Future adaptation	Could potentially affect future flood prevention measures.							
NFM measure benefit realisation	2 yrs+							
Timescales of Works	6 – 12 months							
Estimated Cost to Deliver	High – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain. Likely require working within watercourses with associated H&S and environmental controls to manage construction works.							
Maintenance costs	Low							
Health & Safety	NFM measures will require remote working in upland environment and within watercourses. Works have the potential to be located in areas of steep terrain (i.e. upland streams with steep banks).							
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	Percentage reduction in flow considered insufficient to implement NFM measures and therefore options have not been considered further.
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
New Galloway	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Clatteringshaws	2.5	0.5	0.8	1.3	Medium	Negligible	Negligible	

Loch								
Castle Douglas	0.4	0.2	0.2	0.2	Very High	Negligible	Negligible	
Kirkcubright	0.4	0.1	0.3	0.1	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Social Benefit								
Option Summary								
Measures considered include:								
▪ River bank restoration; Catchments 29, 32, 33, 34, 43, 44 & 49.								
Progress Option to Short List					No			

Option: Castle Douglas – River Reach & Floodplain Storage								
Overview		River Reach and Floodplain Storage NFM Measures in Catchments at Castle Douglas (6, 30, 35, 36, 37, 45, 46, 47, 48)				Measures considered include: ▪ Instream Structures; Catchments 6, 30, 35, 36, 37, 45, 46, 47 & 48 ▪ Riparian Woodland; Catchments 35 & 48 ▪ Washlands & Offline Storage Ponds; Catchment 6		
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		No foreseeable issues with future flood mitigation proposals						
NFM measure benefit realisation		12 – 18 months						
Timescales of Works		6 – 12 months						
Estimated Cost to Deliver		Medium/High – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain.						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment and within watercourses. Works have the potential to be located in areas of steep terrain (i.e. adjacent to upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	Percentage reduction in flow considered insufficient to

New Galloway	0.0	0.0	0.0	0.0	N/A	N/A	N/A	implement NFM measures and therefore options have not been considered further.
Clatteringshaws Loch	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Castle Douglas	1.0	1.2	0.6	1.2	Very High	Negligible	Negligible	
Kirkcubright	0.8	0.9	0.6	1.1	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Flora and Fauna								
Soil								
Water								
Use of natural resources								
Landscape								
Cultural heritage								
Social Benefits								
Option Summary								
Measures considered include: ▪ Instream Structures; Catchments 6, 30, 35, 36, 37, 45, 46, 47 & 48. ▪ Riparian Woodland; Catchments 35 & 48. ▪ Washlands & Offline Storage Ponds; Catchment 6.								
Progress Option to Short List					No			

Option:		Castle Douglas Runoff Reduction						
Overview		Runoff Reduction NFM Measures in Catchments at Castle Douglas (6, 30, 35, 36, 37, 45, 46, 47, 48)				Measures considered include: - Upland drainage modifications; Catchments 6, 30, 35, 36, 37, 45, 46 and 47 - Land and soil management practices; Catchments 35 and 48		
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		No foreseeable issues with future flood mitigation proposals						
NFM measure benefit realisation		2 yrs+						
Timescales of Works		12 – 18 months						
Estimated Cost to Deliver		High – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain.						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment and adjacent to watercourses. Works have the potential to be located in areas of steep terrain (i.e. adjacent to upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	Percentage reduction in flow considered insufficient to implement NFM measures and therefore options have not
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
New Galloway	0.0	0.0	0.0	0.0	N/A	N/A	N/A	

Clatteringshaws Loch	0.0	0.0	0.0	0.0	N/A	N/A	N/A	been considered further.
Castle Douglas	1.2	1.4	0.7	1.2	Very High	Negligible	Negligible	
Kirkcubright	0.9	1.0	0.7	1.1	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Flora and Fauna								
Soil								
Water								
Use of natural resources								
Landscape								
Cultural heritage								
Social Benefits								
Option Summary								
Measures considered include: - Upland drainage modifications; Catchments 6, 30, 35, 36, 37, 45, 46 and 47 - Land and soil management practices; Catchments 35 and 48								
Progress Option to Short List				No				

Option:		Castle Douglas – Sediment Management						
Overview		Sediment Management NFM Measures in Catchments at Castle Douglas (6, 30, 35, 36, 37, 45, 46, 47, 48)			Measures considered include: ▪ River bank restoration; Catchments 6, 30, 35, 36, 37, 45, 46, & 47. ▪ River morphology and floodplain restoration; Catchment 6. ▪ Overland sediment traps; Catchments 35 & 48.			
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		Could potentially affect future flood prevention measures.						
NFM measure benefit realisation		2 yrs+						
Timescales of Works		6 – 12 months						
Estimated Cost to Deliver		High – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain. Likely require working within watercourses with associated H&S and environmental controls to manage construction works.						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment and within watercourses. Works have the potential to be located in areas of steep terrain (i.e. upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	Percentage reduction in flow considered insufficient to

New Galloway	0.0	0.0	0.0	0.0	N/A	N/A	N/A	implement NFM measures and therefore options have not been considered further.
Clatteringshaws Loch	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Castle Douglas	1.4	1.7	1.0	1.4	Very High	Negligible	Negligible	
Kirkcubright	1.3	1.3	1.0	1.4	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Social Benefit								
Option Summary								
Measures considered include: - River bank restoration; Catchments 6, 30, 35, 36, 37, 45, 46, & 47. - River morphology and floodplain restoration; Catchment 6. - Overland sediment traps; Catchments 35 & 48.								
Progress Option to Short List					No			

Option: Kirkcudbright – River Reach & Floodplain Storage								
Overview		River Reach and Floodplain Storage NFM Measures in Catchments at Kirkcudbright (6, 30, 35, 36, 37, 45, 46, 47, 48)				Measures considered include: ▪ Instream Structures; Catchments 6, 30, 35, 36, 37, 45, 46, 47 & 48 ▪ Riparian Woodland; Catchments 35 & 48 ▪ Washlands & Offline Storage Ponds; Catchment 6		
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		No foreseeable issues with future flood mitigation proposals						
NFM measure benefit realisation		12 – 18 months						
Timescales of Works		6 – 12 months						
Estimated Cost to Deliver		Medium/High – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain.						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment and within watercourses. Works have the potential to be located in areas of steep terrain (i.e. adjacent to upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	Percentage reduction in flow considered insufficient to

New Galloway	0.0	0.0	0.0	0.0	N/A	N/A	N/A	implement NFM measures and therefore options have not been considered further.
Clatteringshaws Loch	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Castle Douglas	1.0	1.2	0.6	1.2	Very High	Negligible	Negligible	
Kirkcubright	0.8	0.9	0.6	1.1	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Flora and Fauna								
Soil								
Water								
Use of natural resources								
Landscape								
Cultural heritage								
Social Benefits								
Option Summary								
Measures considered include: ▪ Instream Structures; Catchments 6, 30, 35, 36, 37, 45, 46, 47 & 48. ▪ Riparian Woodland; Catchments 35 & 48. ▪ Washlands & Offline Storage Ponds; Catchment 6.								
Progress Option to Short List					No			

Option: Kirkcudbright – Runoff Reduction								
Overview		Runoff Reduction NFM Measures in Catchments at Kirkcudbright (6, 30, 35, 36, 37, 45, 46, 47, 48)				Measures considered include: - Upland drainage modifications; Catchments 6, 30, 35, 36, 37, 45, 46 and 47 - Land and soil management practices; Catchments 35 and 48		
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		No foreseeable issues with future flood mitigation proposals						
NFM measure benefit realisation		2 yrs+						
Timescales of Works		12 – 18 months						
Estimated Cost to Deliver		High – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain.						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment and adjacent to watercourses. Works have the potential to be located in areas of steep terrain (i.e. adjacent to upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	Percentage reduction in flow considered insufficient to implement NFM measures and therefore options have not
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
New Galloway	0.0	0.0	0.0	0.0	N/A	N/A	N/A	

Clatteringshaws Loch	0.0	0.0	0.0	0.0	N/A	N/A	N/A	been considered further.
Castle Douglas	1.2	1.4	0.7	1.2	Very High	Negligible	Negligible	
Kirkcubright	0.9	1.0	0.7	1.1	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Flora and Fauna								
Soil								
Water								
Use of natural resources								
Landscape								
Cultural heritage								
Social Benefits								
Option Summary								
Measures considered include: - Upland drainage modifications; Catchments 6, 30, 35, 36, 37, 45, 46 and 47 - Land and soil management practices; Catchments 35 and 48								
Progress Option to Short List				No				

Option: Kirkcudbright – Sediment Management								
Overview		Sediment Management NFM Measures in Catchments at Castle Douglas (6, 30, 35, 36, 37, 45, 46, 47, 48)			Measures considered include: - River bank restoration; Catchments 6, 30, 35, 36, 37, 45, 46, & 47. - River morphology and floodplain restoration; Catchment 6. - Overland sediment traps; Catchments 35 & 48.			
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		Could potentially affect future flood prevention measures.						
NFM measure benefit realisation		2 yrs+						
Timescales of Works		6 – 12 months						
Estimated Cost to Deliver		High – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain. Likely require working within watercourses with associated H&S and environmental controls to manage construction works.						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment and within watercourses. Works have the potential to be located in areas of steep terrain (i.e. upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	Percentage reduction in flow considered insufficient to

New Galloway	0.0	0.0	0.0	0.0	N/A	N/A	N/A	implement NFM measures and therefore options have not been considered further.
Clatteringshaws Loch	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Castle Douglas	1.4	1.7	1.0	1.4	Very High	Negligible	Negligible	
Kirkcubright	1.3	1.3	1.0	1.4	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Social Benefit								
Option Summary								
Measures considered include: - River bank restoration; Catchments 6, 30, 35, 36, 37, 45, 46, & 47. - River morphology and floodplain restoration; Catchment 6. - Overland sediment traps; Catchments 35 & 48.								
Progress Option to Short List					No			

Option:	Carsphairn – Sediment Management							
Overview	Sediment Management NFM Measures in Catchments upstream of Carsphairn (38, 39, 40, 41 & 42)				Measures considered include: - River bank restoration; Catchments 38, 39, 41 and 42. - Overland sediment traps; Catchments 40, 41 and 42.			
Feasibility Issues	Landowner acceptance Funding							
Future adaptation	Could potentially affect future flood prevention measures.							
NFM measure benefit realisation	2 yrs+							
Timescales of Works	6 – 12 months							
Estimated Cost to Deliver	High – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain. Likely require working within watercourses with associated H&S and environmental controls to manage construction works.							
Maintenance costs	Low							
Health & Safety	NFM measures will require remote working in upland environment and within watercourses. Works have the potential to be located in areas of steep terrain (i.e. upland streams with steep banks).							
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	1.5	1.6	1.6	1.3	High	Negligible	Negligible	Percentage reduction in flow considered insufficient to implement NFM measures and therefore options have not been considered further.
Dalry Floodplain	0.8	0.6	0.7	0.6	Medium	Negligible	Negligible	
New Galloway	0.8	0.6	0.6	0.5	Medium	Negligible	Negligible	
Clatteringshaws	0.0	0.0	0.0	0.0	N/A	N/A	N/A	

Loch								
Castle Douglas	0.6	0.3	0.1	0.4	Very High	Negligible	Negligible	
Kirkcubright	0.5	0.2	0.1	0.3	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Social Benefit								
Option Summary								
Measures considered include: - River bank restoration; Catchments 38, 39, 41 and 42. - Overland sediment traps; Catchments 40, 41 and 42.								
Progress Option to Short List				No				

Option: Dalry Floodplain – River Reach & Floodplain Storage								
Overview		River Reach and Floodplain Storage NFM Measures in Catchments at Dalry Floodplain (52)				Measures considered include: ▪ Washlands & Offline Storage Ponds; Catchment 52 ▪ Floodplain woodland; Catchment 52		
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		No foreseeable issues with future flood mitigation proposals						
NFM measure benefit realisation		2 yrs+						
Timescales of Works		6 – 12 months						
Estimated Cost to Deliver		Medium –plant / machinery working in relatively remote locations with potentially relatively difficult access and terrain.						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment and adjacent to watercourses. Works have the potential to be located in areas of steep terrain (i.e. adjacent to upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	Percentage reduction in flow considered insufficient to implement NFM measures and therefore options have not been considered further.
Dalry Floodplain	0.6	0.6	0.4	0.4	Medium	Negligible	Negligible	
New Galloway	0.6	0.5	0.4	0.4	Medium	Negligible	Negligible	
Clatteringshaws Loch	0.0	0.0	0.0	0.0	N/A	N/A	N/A	

Castle Douglas	0.4	0.5	0.3	0.3	Very High	Negligible	Negligible	
Kirkcubright	0.3	0.3	0.4	0.2	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification			Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions	
Flora and Fauna								
Soil								
Water								
Use of natural resources								
Landscape								
Cultural heritage								
Social Benefits								
Option Summary								
Measures considered include: - Washlands & Offline Storage Ponds; Catchment 52 - Floodplain woodland; Catchment 52								
Progress Option to Short List				No				

Option: New Galloway – River Reach & Floodplain Storage								
Overview		River Reach and Floodplain Storage NFM Measures in Catchments at New Galloway (31)				Measures considered include: Riparian Woodland; Catchment 31		
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		No foreseeable issues with future flood mitigation proposals						
NFM measure benefit realisation		2 yrs+						
Timescales of Works		6 – 12 months						
Estimated Cost to Deliver		Medium – works requiring contractors with plant / machinery working in remote locations with difficult access and terrain adjacent to watercourses.						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment adjacent to watercourses. Works have the potential to be located in areas of steep terrain (i.e. adjacent to upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	Percentage reduction in flow considered insufficient to implement NFM measures and therefore options have not been considered further.
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
New Galloway	2.0	1.3	0.0	0.7	Medium	Negligible	Negligible	
Clatteringshaws	0.0	0.0	0.0	0.0	N/A	N/A	N/A	

Loch								
Castle Douglas	0.0	0.0	0.0	0.0	Very High	Negligible	Negligible	
Kirkcubright	0.0	0.0	0.0	0.0	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Flora and Fauna								
Soil								
Water								
Use of natural resources								
Landscape								
Cultural heritage								
Social Benefits								
Option Summary								
Measures considered include: Riparian Woodland; Catchment 31								
Progress Option to Short List					No			

Long List Measures Taken Forward



Option:		Carsphairn – Runoff Reduction							
Overview		Runoff Reduction NFM Measures in Catchments upstream of Carsphairn (38, 39, 40, 41 & 42)				Measures considered include: - Land and Soil Management Practices; Catchments 40, 41 & 42 - Riparian Woodland; Catchments 38, 39, 40, 41 & 42 - Upland Drainage Modifications; Catchments 38, 39, 40, 41 & 42			
Feasibility Issues		Landowner acceptance Funding							
Future adaptation		No foreseeable issues with future flood mitigation proposals							
NFM measure benefit realisation		2 yrs+							
Timescales of Works		12 – 18 months							
Estimated Cost to Deliver		Medium – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain.							
Maintenance costs		Low							
Health & Safety		NFM measures will require remote working in upland environment and adjacent to watercourses. Works have the potential to be located in areas of steep terrain (i.e. adjacent to upland streams with steep banks).							
Land Owner Involved: Name: Address: Details of contact:									
Benefit Assessment									
Hydrological Benefit									
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions	
	1:2	1:10	1:50	1:200					
Carsphairn	23.4	16.9	13.0	10.6	High	Very Large	Very High		
Dalry Floodplain	6.0	4.8	4.3	3.6	Medium	Small	Low		

New Galloway	5.7	4.4	3.9	3.3	Medium	Small	Low	
Clatteringshaws Loch	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Castle Douglas	2.9	2.2	1.8	1.7	Very High	Very Small	Low	
Kirkcudbright	2.6	2.2	1.9	1.7	Very High	Very Small	Low	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Flora and Fauna	Flows into the River Dee which is a Category 3 salmon conservation river.				High	Medium	High	NFM measures have the potential to provide a positive benefit due to habitat improvement. Improvements are unlikely to have no effect on salmon because no river / ground water works are required.
Soil	Improving soil quality Majority of the catchment is classed as 5. Small areas of the catchment are classed as a nationally important soil resource (classes 1 & 2) with the lower reaches classed as being soils that are associated with not being a priority peatland habitat but are associated with wet and acidic conditions (3).				Medium	Medium	Moderate	NFM measures have the potential to improve the quality of the soil via the improved retention of water via upland drainage modifications. The consideration of woodland planting as well as hedgerows has the potential to provide a positive impact via a reduction in the erosion of soils from watercourse banks as well as through overland sheet flow
Water	Pressures result in poor WFD status of the Carsphairn Lane, Water of Deugh, Bow Burn and Garryhorn Burn catchments. It is currently assumed that this status applies to the associated				High	Medium	High	The NFM measures are unlikely to change the WFD status of the overall catchments due to the existing and potential future catchment pressures as well as the spatial extent of measures considered. However, implementation of NFM has the potential to

	tributary catchments				provide improvements to tributary catchments at a local scale. There are no proposals to reduce existing structures on watercourses or alter existing hydropower operations.
Use of natural resources	NFM measures would utilise natural processes and materials.	High	Medium	High	Enhancing existing flood plain capacity. Utilising natural resources.
Landscape	Dominated by upland and forestry landscape character types	Medium	Low Small	Very low	Small scale change using native plants. Unlikely to alter landscape character
Cultural heritage	No direct impacts	N/A	N/A	N/A	All measures will avoid direct impact on cultural heritage designations
Social Benefits					
Benefits through reduced flood risk. Potential to enhance community engagement and interaction through implementation of a pilot project. Increased biodiversity and potential enhanced access to new amenity areas.					
Option Summary					
Measures considered include: - Land and Soil Management Practices; Catchments 38 & 39, - Riparian Woodland; Catchments 38, 39, 40, & 41. Woodland should include deciduous trees as far as possible. - Upland Drainage Modifications; Catchments 38 & 39, - Agricultural and Upland Drainage Modifications; Catchments 41 & 42.					
Progress Option to Short List		Yes			

Option: Carsphairn – River Reach & Floodplain Storage								
Overview		River Reach and Floodplain Storage NFM Measures in Catchments upstream of Carsphairn (38, 39, 40, 41 & 42)				Measures considered include: ▪ Instream Structures; Catchments 38, 39, 40, 41 & 42 ▪ Floodplain Woodland; Catchments 40, 41 & 42 ▪ Riparian Woodland; Catchment 38, 39, 40, 41 & 42 ▪ Washlands & Offline Storage Ponds; Catchment 42		
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		No foreseeable issues with future flood mitigation proposals						
NFM measure benefit realisation		12 – 18 months						
Timescales of Works		6 – 12 months						
Estimated Cost to Deliver		High – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain.						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment and within watercourses. Works have the potential to be located in areas of steep terrain (i.e. adjacent to upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	10.3	7.8	6.2	5.2	High	Medium	High	
Dalry Floodplain	3.8	3.1	2.7	2.6	Medium	Very Small	Very Low	

New Galloway	3.4	2.9	2.4	2.3	Medium	Very Small	Very Low	
Clatteringshaws Loch	0	0	0	0	N/A	N/A	N/A	
Castle Douglas	2.0	1.6	1.1	1.2	Very High	Negligible	Negligible	
Kirkcudbright	1.7	1.5	1.1	1.2	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Flora and Fauna	Improving habitat biodiversity. Flows into the River Dee which is a Category 3 salmon conservation river.				High	Medium	High	Instream structures has the potential to be negative when considered on the whole but with mitigation, limiting measures to instream structures in the upland headwater only will ensure passage of fish leading to no negative impact. Floodplain and/or riparian woodland have the potential to provide a positive impact via the creation of potential habitat Washland and/or offline storage ponds have the potential to create additional habitat.
Soil	Improving soil quality Majority of the catchment is classed as 5. Small areas of the catchment are classed as a nationally important soil resource (classes 1 & 2) with the lower reaches classed as being soils that are associated with not being a priority peatland				Medium	Medium	Moderate	NFM measures have the potential to improve the quality of the soil via the improved retention of water via upland drainage modifications. The consideration of woodland planting as well as washland and offline storage ponds has the potential to provide a positive impact via a reduction in the erosion of soils from watercourse banks as well as through overland sheet flow

	habitat but are associated with wet and acidic conditions (3).				
Water	Pressures result in poor WFD status of the Carsphairn Lane, Water of Deugh, Bow Burn and Garryhorn Burn catchments. It is currently assumed that this status applies to the associated tributary catchments	High	Small	Very low	The NFM measures are unlikely to change the WFD status of the overall catchments due to the existing and potential future catchment pressures as well as the spatial extent of measures considered. However, implementation of NFM has the potential to provide improvements to tributary catchments at a local scale. There are no proposals to reduce existing structures on watercourses or alter existing hydropower operations.
Use of natural resources	NFM measures would utilise natural processes and materials.	High	Medium	High	Enhancing existing flood plain capacity. Utilising natural resources.
Landscape	Dominated by upland and forestry landscape character types	Medium	Low Small	Very low	Small scale change using native plants. Unlikely to alter landscape character.
Cultural heritage	No direct impacts	N/A	N/A	N/A	All measures will avoid direct impact on cultural heritage designations.
Social Benefits					
Benefits through reduced flood risk. Potential to enhance community engagement and interaction through implementation of a pilot project. Increased biodiversity and potential enhanced access to new amenity areas.					
Option Summary					
Measures considered include: ▪ Instream Structures on Catchments 38, 39, 40, 41 & 42. Instream structures should be limited to the upland headwaters to avoid issues with migratory fish. ▪ Floodplain Woodland; Catchments 40 & 42. Woodland should include deciduous trees as far as possible. ▪ Riparian Woodland; Catchment 41. Woodland should include deciduous trees as far as possible. ▪ Washlands & Offline Storage Ponds; Catchment 42.					
Progress Option to Short List		Yes			

Option:		Clatteringshaws Loch – Runoff Reduction						
Overview		Runoff Reduction NFM Measures in Catchments at Clatteringshaws Loch (29, 32, 33, 34, 43, 44 ,49)			Measures considered include: - Land and Soil Management Practices; Catchments 29, 32, 33, 34, 43, 44 & 49. - Upland Drainage Modifications; Catchments 29, 32, 33, 34, 43, 44 & 49.			
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		No foreseeable issues with future flood mitigation proposals						
NFM measure benefit realisation		2+ yrs (depends on forestry cycle)						
Timescales of Works		2+ yrs (depends on forestry cycle)						
Estimated Cost to Deliver		Low – assuming Forestry Commission implement						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment and adjacent to watercourses. Works have the potential to be located in areas of steep terrain (i.e. adjacent to upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:		All surrounding land is Forestry Commission owned. All forestry operation and future planting will be to current best practice guidance. Design plans will be agreed with all statutory consultees.						
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
New Galloway	0.0	0.0	0.0	0.0	N/A	N/A	N/A	

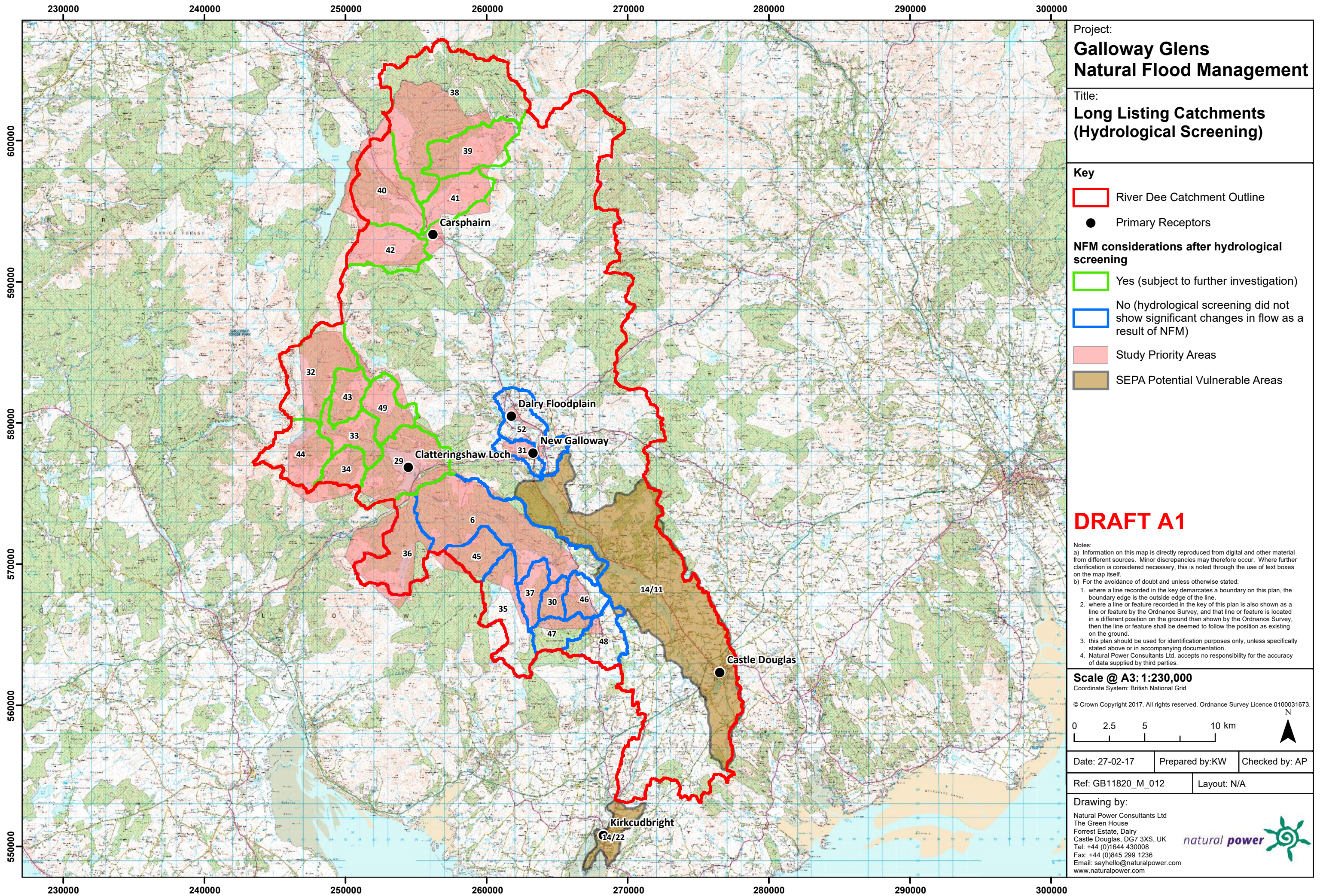
Clatteringshaws Loch	16.7	9.8	7.5	7.1	Medium	Very Large	High	
Castle Douglas	2.8	1.9	1.1	1.1	Very High	Very Small	Low	
Kirkcubright	2.6	1.8	1.2	1.1	Very High	Very Small	Low	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Flora and Fauna	3 x SSSI's, 1 x SAC's - Blanket bog. Remainder predominantly plantation forestry				High	Medium	High	Based on improving existing SSSI's and wider improvement to forestry
Soil	Improving soil quality Majority of the catchment is classed as 5. Small areas of the catchment are classed as a nationally important soil resource (classes 1 & 2). Significant areas of the catchment also classed as 3 or 4 which represents soils that are unlikely to be priority peatland habitat but are associated with wet and acidic conditions.				High	Medium	High	NFM measures have the potential to improve the quality of the soil via the improved retention of water via upland drainage modifications. Upland drainage modifications have the potential to support the outcomes of Peatland Action by improving carbon sequestration within drained peatlands and peaty soils.
Water	Pressures result in poor WFD status of the Black Water of Dee and Garrary Burn catchments. Clatteringshaws Loch classed as having moderate status. It is currently assumed that this status applies to the associated				High	Small	Medium	The NFM measures are unlikely to change the WFD status of the overall catchments due to the existing and potential future catchment pressures as well as the spatial extent of measures considered. However, implementation of NFM has the potential to provide improvements to tributary catchments at a local

	tributary catchments				scale. There are no proposals to reduce existing structures on watercourses or alter existing hydropower operations.
Use of natural resources	NFM measures would utilise natural processes and materials.	High	Medium	High	Enhancing existing flood plan capacity. Utilising natural resources.
Landscape	Dominated by upland and forestry landscape character types	Medium	Low Small	Very low	Small scale change using native plants. Unlikely to alter landscape character
Cultural heritage	N/A	N/A	N/A		All measures will avoid direct impact on cultural heritage designations
Social Benefits					
Benefits through reduced flood risk. Potential to enhance community engagement and interaction through implementation of a pilot project. Increased biodiversity and potential enhanced access to new amenity areas. Improved communication and understanding between local residents and Forestry Commission operations and management.					
Option Summary					
Measures considered include: - Land and Soil Management Practices; Catchments 29, 32, 33, 34, 43, 44 & 49. - Upland Drainage Modifications; Catchments 29, 32, 33, 34, 43, 44 & 49.					
Progress Option to Short List		Yes			

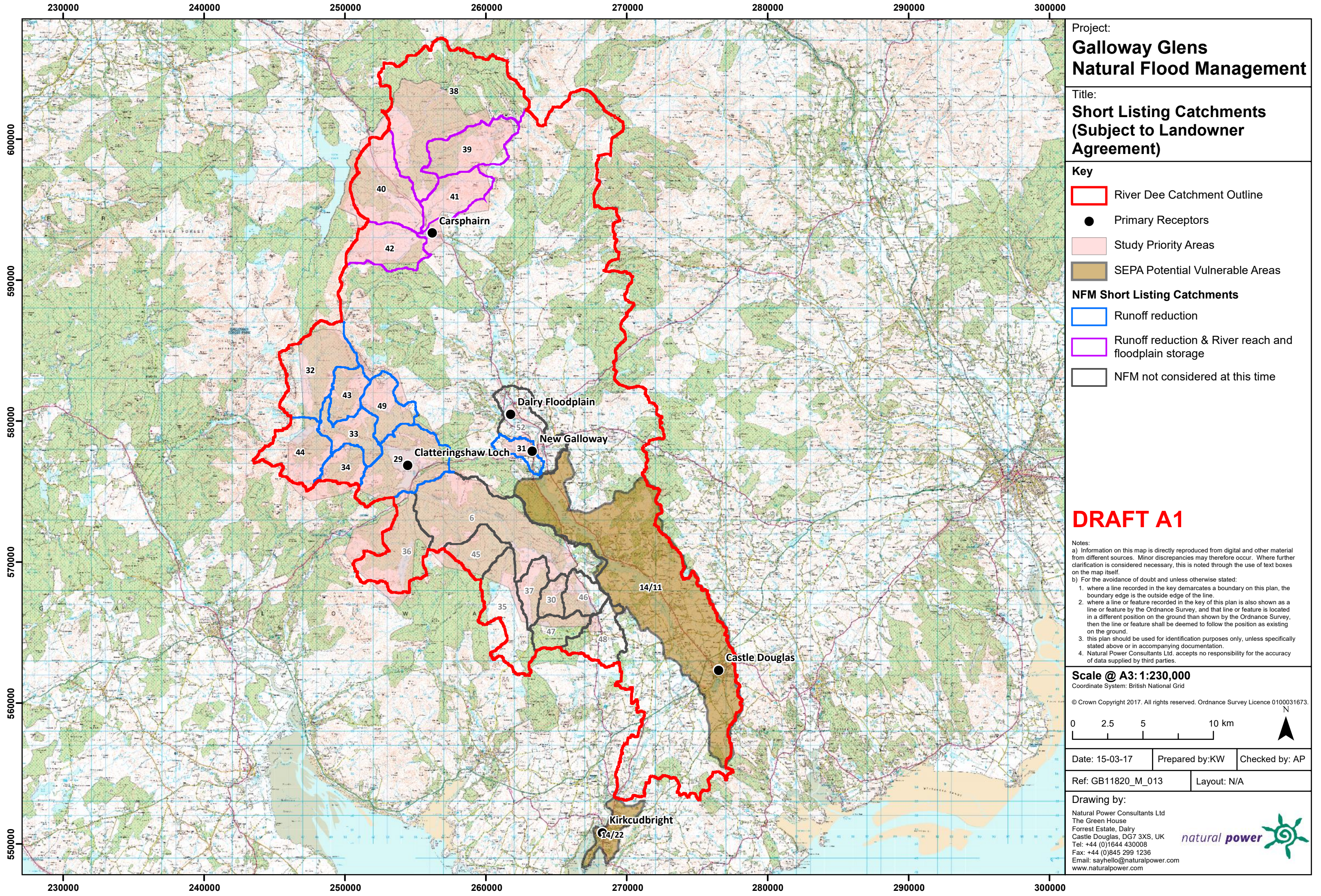
Option:		New Galloway – Runoff Reduction						
Overview		Runoff Reduction NFM Measures in Catchments at New Galloway (31)) Measures considered include: - Land and Soil Management Practices; Catchment 31 - Riparian Woodland; Catchments 31						
Feasibility Issues		Landowner acceptance Funding						
Future adaptation		No foreseeable issues with future flood mitigation proposals						
NFM measure benefit realisation		2 yrs+						
Timescales of Works		12 – 18 months						
Estimated Cost to Deliver		Low – potential excavation works requiring contractors with plant / machinery working in remote locations with difficult access and terrain.						
Maintenance costs		Low						
Health & Safety		NFM measures will require remote working in upland environment and adjacent to watercourses. Works have the potential to be located in areas of steep terrain (i.e. adjacent to upland streams with steep banks).						
Land Owner Involved: Name: Address: Details of contact:								
Benefit Assessment								
Hydrological Benefit								
Compliance Point	% Reduction in Flows for Return Period				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
	1:2	1:10	1:50	1:200				
Carsphairn	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
Dalry Floodplain	0.0	0.0	0.0	0.0	N/A	N/A	N/A	
New Galloway	7.8	6.6	4.6	4.1	Medium	Small	Low	
Clatteringshaws Loch	0.0	0.0	0.0	0.0	N/A	N/A	N/A	

Castle Douglas	0.1	0.1	0.0	0.0	Very High	Negligible	Negligible	
Kirkcubright	0.1	0.1	0.0	0.0	Very High	Negligible	Negligible	
Environmental Benefit								
Environmental Receptor	Description and Quantification				Importance of Impacted Receptor	Magnitude of Impact	Benefit Outcome	Notes / Assumptions
Flora and Fauna	One SSSI (Kenmure Holms) immediately downstream. SPA on catchment boundary.				High	Small	Medium	
Soil	No carbon or peatland classifications. SNH Carbon Soils and Priority Peatland Habitats classes the catchment				Low	Small	Very Low	The consideration of NFM woodland planting as well as hedgerows has the potential to provide a positive impact via a reduction in the erosion of soils from watercourse banks as well as through overland sheet flow
Water	Bad WFD status of Water of Ken catchment due to existing pressures. Moderate WFD status of the Knocknairling Burn. catchment				High	Small	Moderate	Assumed similar Moderate status associated with the Knocknairling Burn can also apply to Mill Burn due to small size of catchment The NFM measures are unlikely to change the WFD status of the overall catchments due to the existing and potential future catchment pressures as well as the spatial extent of measures considered. However, implementation of NFM has the potential to provide improvements to tributary catchments at a local scale. There are no proposals to reduce existing structures on watercourses or alter existing hydropower operations.
Use of natural resources					High	Medium	High	Enhancing existing flood plan capacity. Utilising natural resources.
Landscape	Upland rough grazing land				Medium	Low Small	Very low	Small scale change using native plants. Unlikely to alter

	character				landscape character
Cultural heritage	No direct impacts	N/A	N/A	N/A	All measures will avoid direct impact on cultural heritage designations
Social Benefits					
Benefits through reduced flood risk. Potential to enhance community engagement and interaction through implementation of a pilot project. Increased biodiversity and potential enhanced access to new amenity areas.					
Option Summary					
Measures considered include: ▪ Land and Soil Management Practices; Catchment 31 ▪ Riparian Woodland; Catchments 31 . Woodland should include deciduous trees as far as possible. ▪ Upland Drainage Modifications; Catchment 31					
Progress Option to Short List		Yes			



Appendix D – Short List NFM Measures for Initial Option Appraisal



Project:
**Galloway Glens
Natural Flood Management**

Title:
**Short Listing Catchments
(Subject to Landowner
Agreement)**

- Key**
- River Dee Catchment Outline
 - Primary Receptors
 - Study Priority Areas
 - SEPA Potential Vulnerable Areas
- NFM Short Listing Catchments**
- Runoff reduction
 - Runoff reduction & River reach and floodplain storage
 - NFM not considered at this time

DRAFT A1

Notes:
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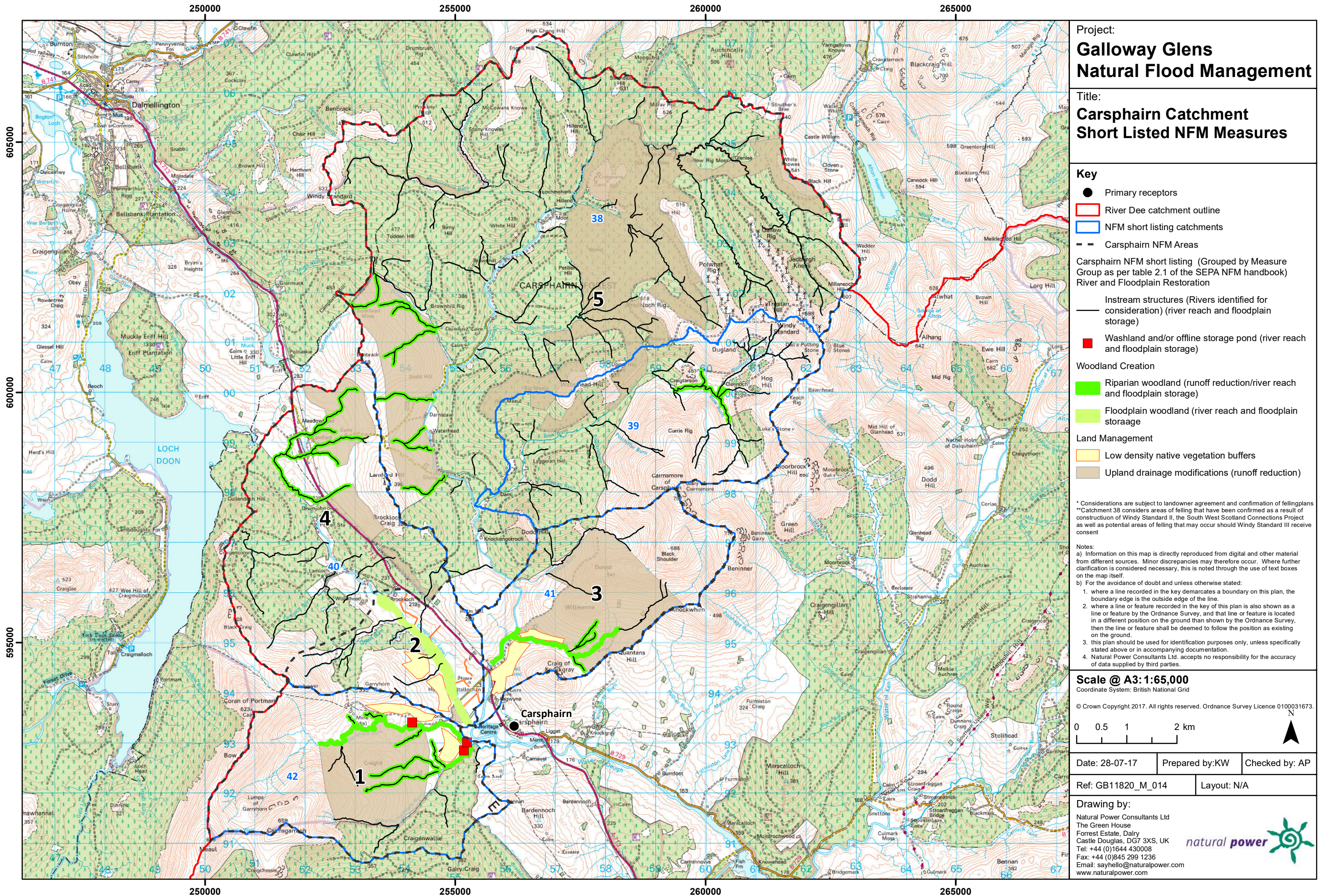
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Date: 15-03-17 Prepared by: KW Checked by: AP

Ref: GB11820_M_013 Layout: N/A

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Project:
**Galloway Glens
Natural Flood Management**

Title:
**Carsphairn Catchment
Short Listed NFM Measures**

- Key**
- Primary receptors
 - ▭ River Dee catchment outline
 - ▭ NFM short listing catchments
 - - Carsphairn NFM Areas
- Carsphairn NFM short listing (Grouped by Measure Group as per table 2.1 of the SEPA NFM handbook)
- River and Floodplain Restoration
- ▭ Instream structures (Rivers identified for consideration) (river reach and floodplain storage)
 - ▭ Washland and/or offline storage pond (river reach and floodplain storage)
- Woodland Creation
- ▭ Riparian woodland (runoff reduction/river reach and floodplain storage)
 - ▭ Floodplain woodland (river reach and floodplain storage)
- Land Management
- ▭ Low density native vegetation buffers
 - ▭ Upland drainage modifications (runoff reduction)

* Considerations are subject to landowner agreement and confirmation of felling plans
** Catchment 38 considers areas of felling that have been confirmed as a result of construction of Windy Standard II, the South West Scotland Connections Project as well as potential areas of felling that may occur should Windy Standard III receive consent

- Notes:
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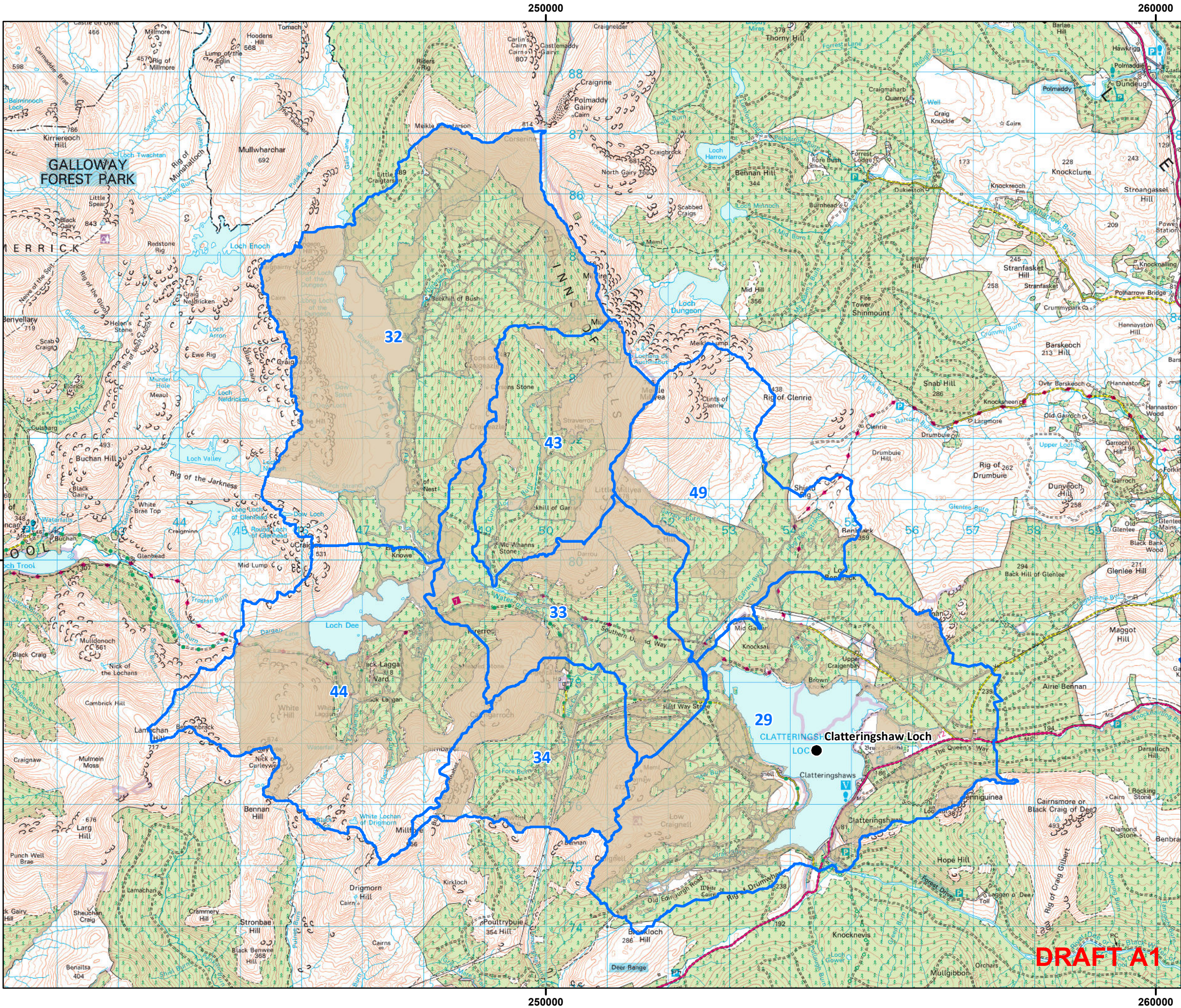
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Date: 28-07-17	Prepared by: KW	Checked by: AP
Ref: GB11820_M_014	Layout: N/A	

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Project:
**Galloway Glens
Natural Flood Management**

Title:
**Clatteringshaw Loch
Short Listed NFM Measures**

Key

- Primary Receptors
- NFM Short Listing Catchments
- Upland Drainage Modifications*

Areas considered for upland drainage management are based on the National Forest Inventory and areas identified as being "Felled", "Open", "Unplantable or bare" and "Unplanted Streambanks".

Data downloaded from Forestry Commission website on 23rd March 2017 at <https://www.forestry.gov.uk/datadownload>.

Suitability of areas for upland drainage modification will be subject to approval from Forestry Commission Scotland

Notes:
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b) For the avoidance of doubt and unless otherwise stated:

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Date: 23-03-17 Prepared by: KW Checked by: AP

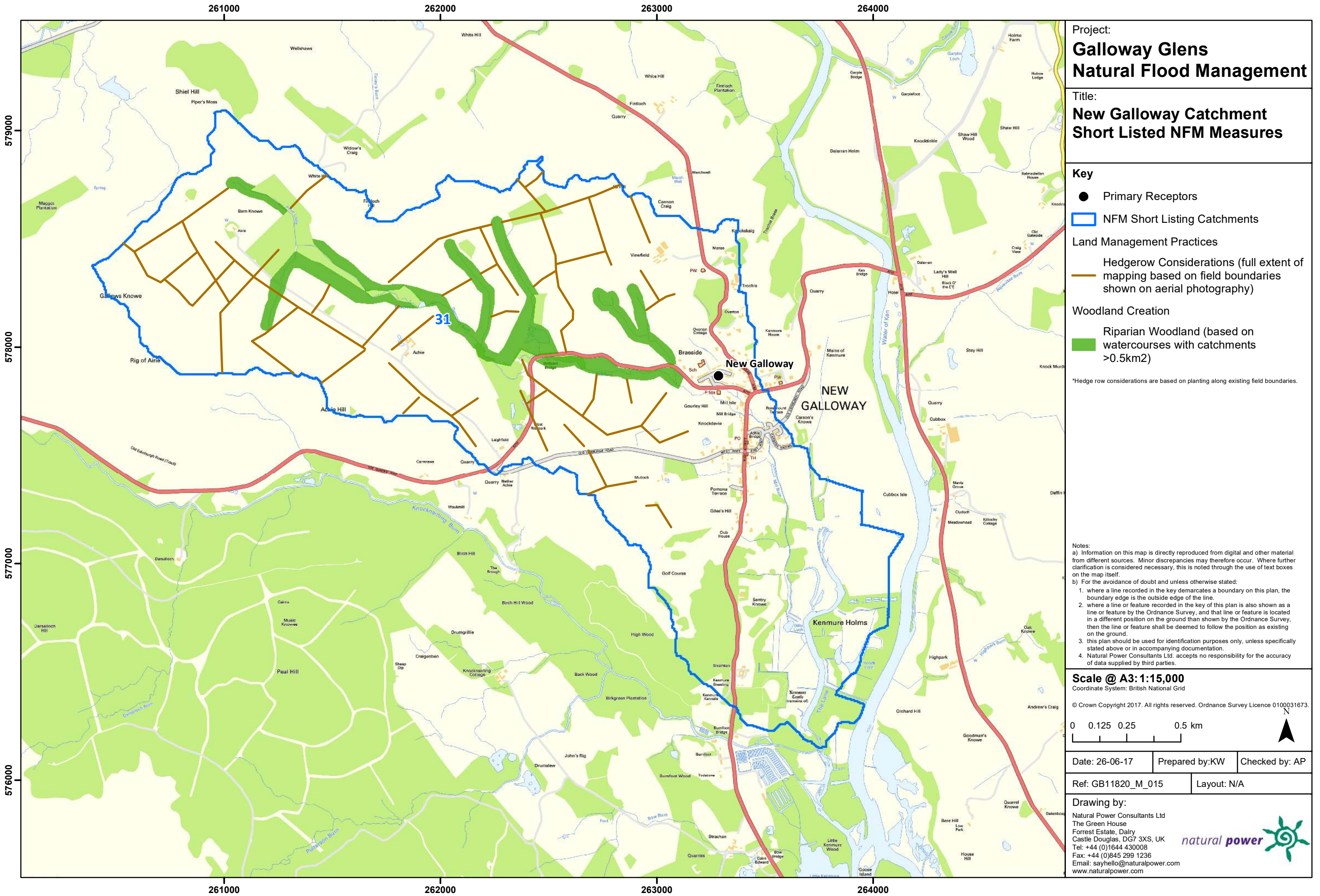
Ref: GB11820_M_016 Layout: N/A

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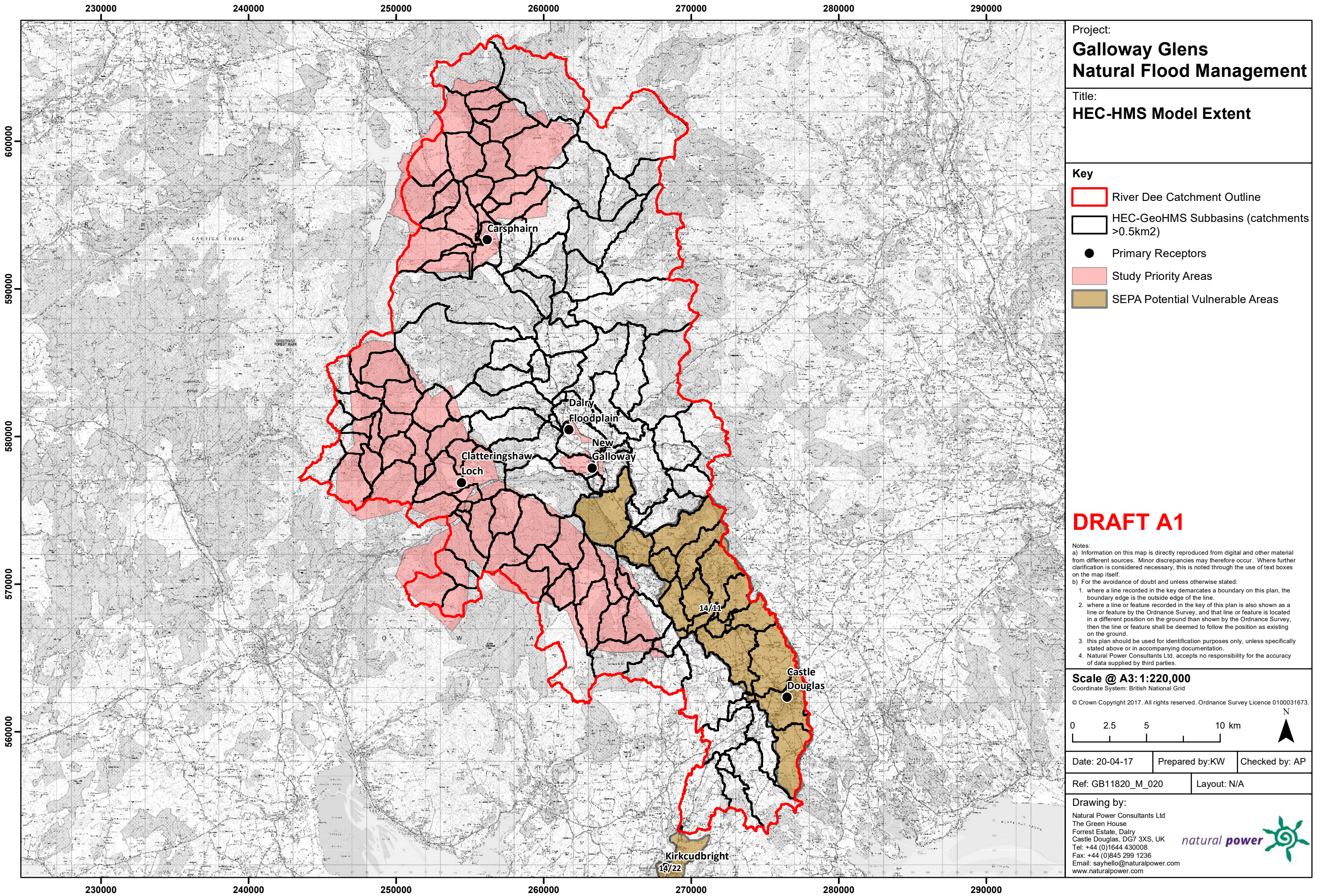


Appendix E – Hydrological Model Figures, Results and Tables



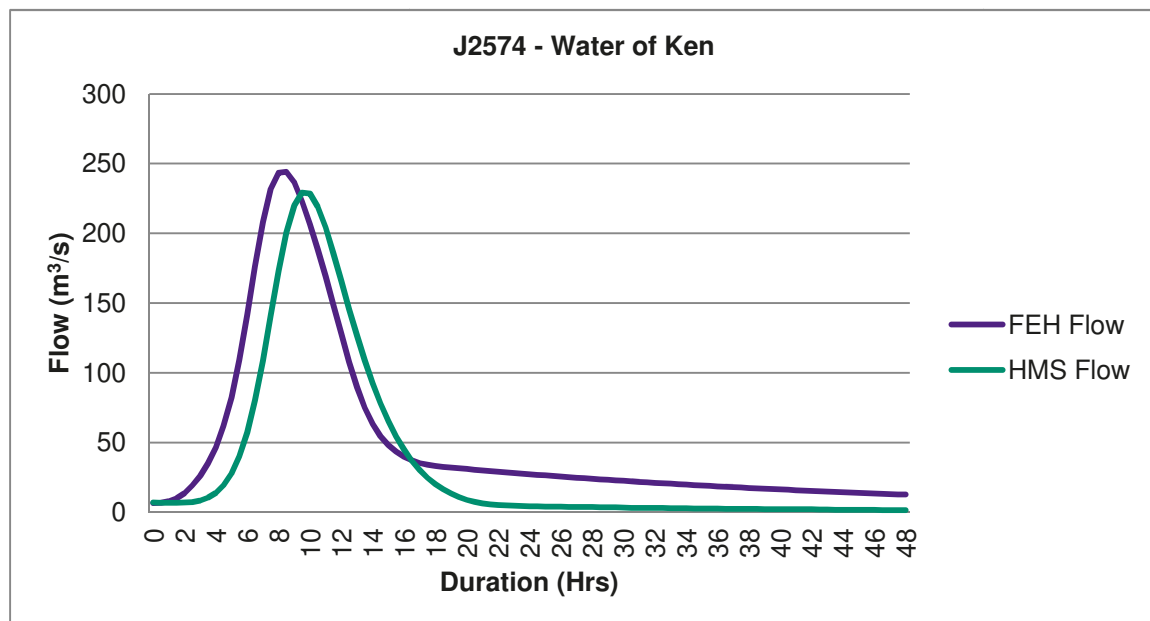
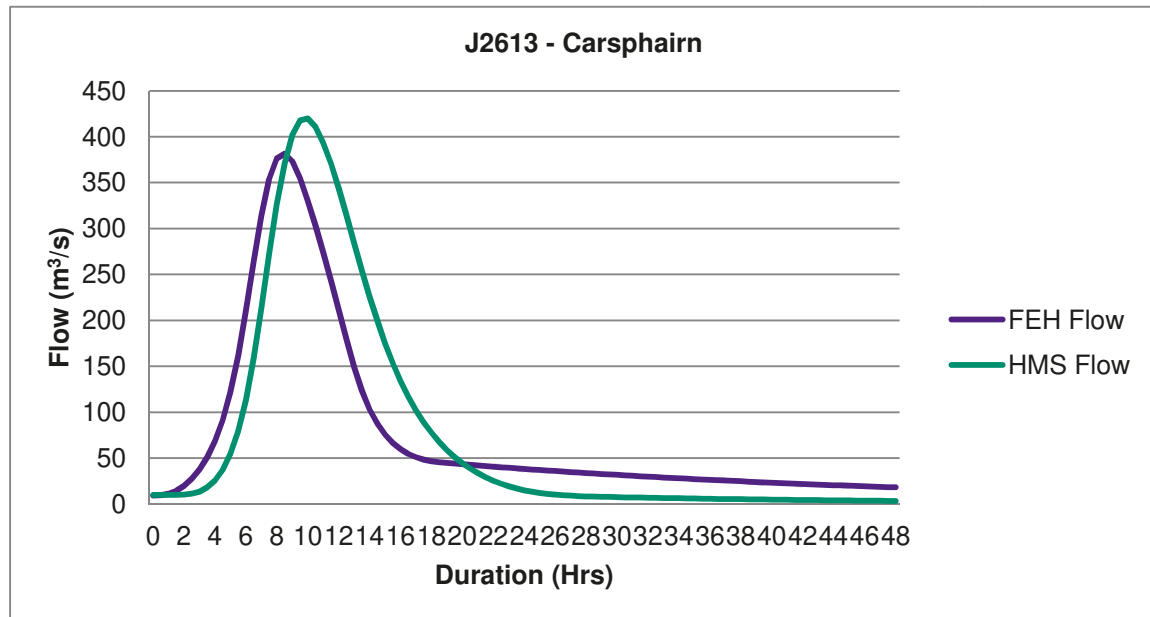
Hydrological Model Figures

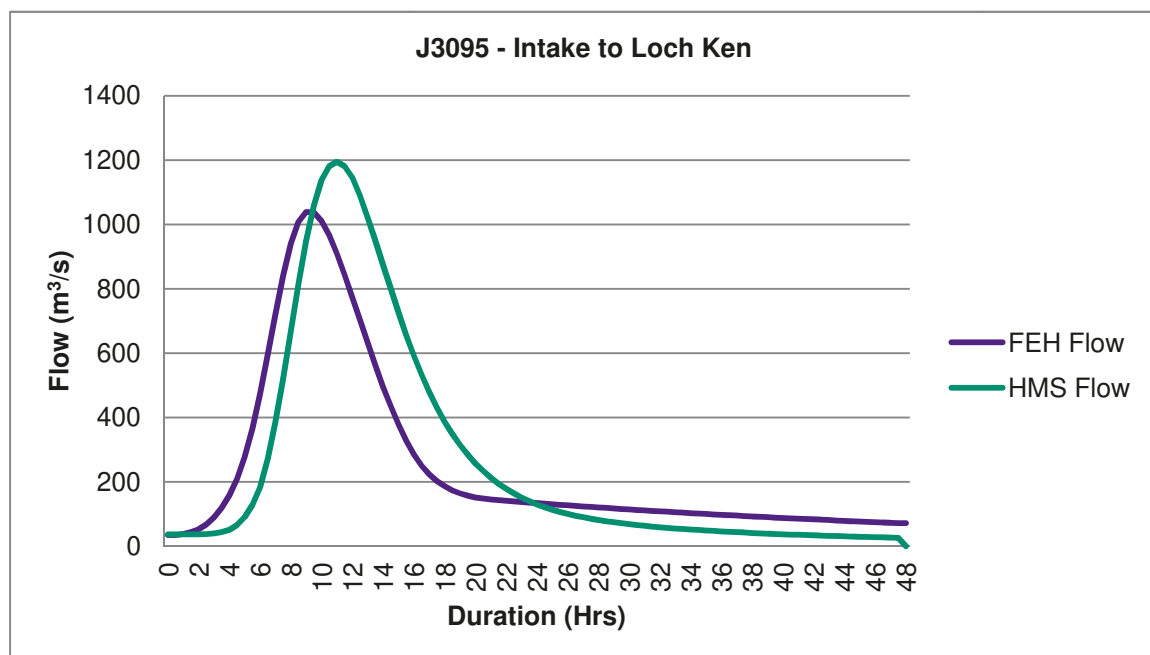
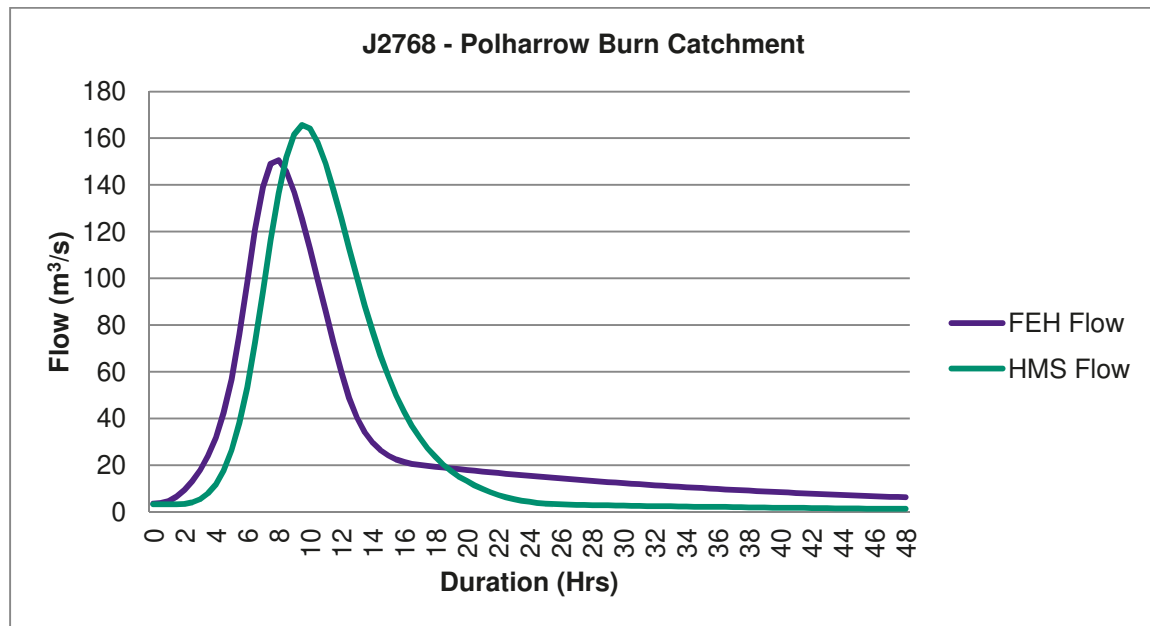


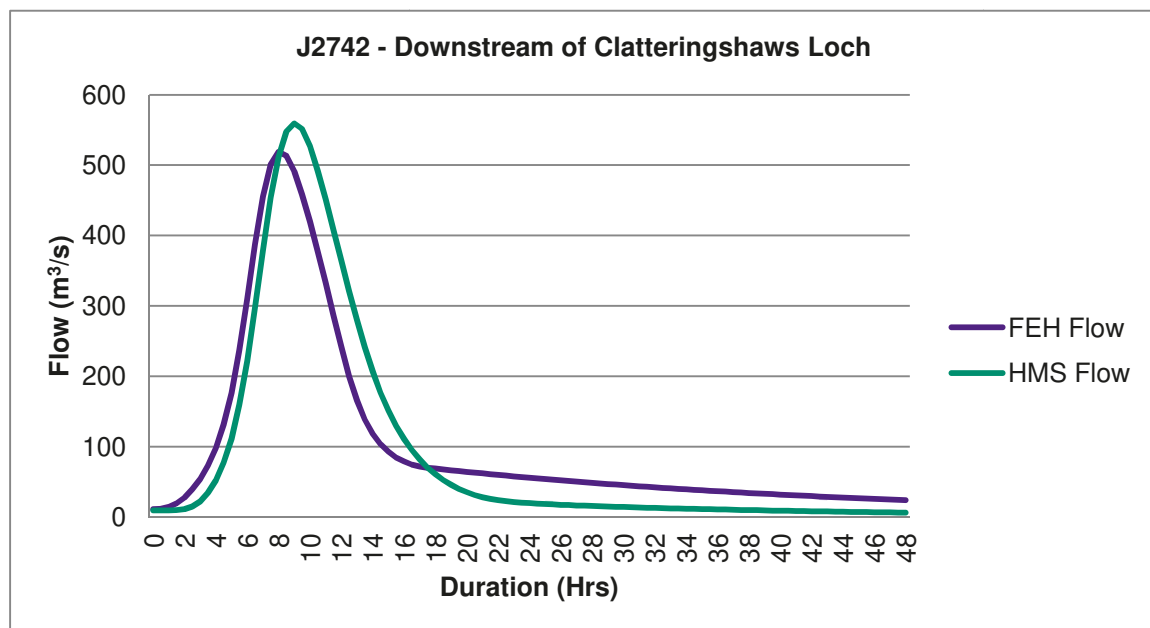
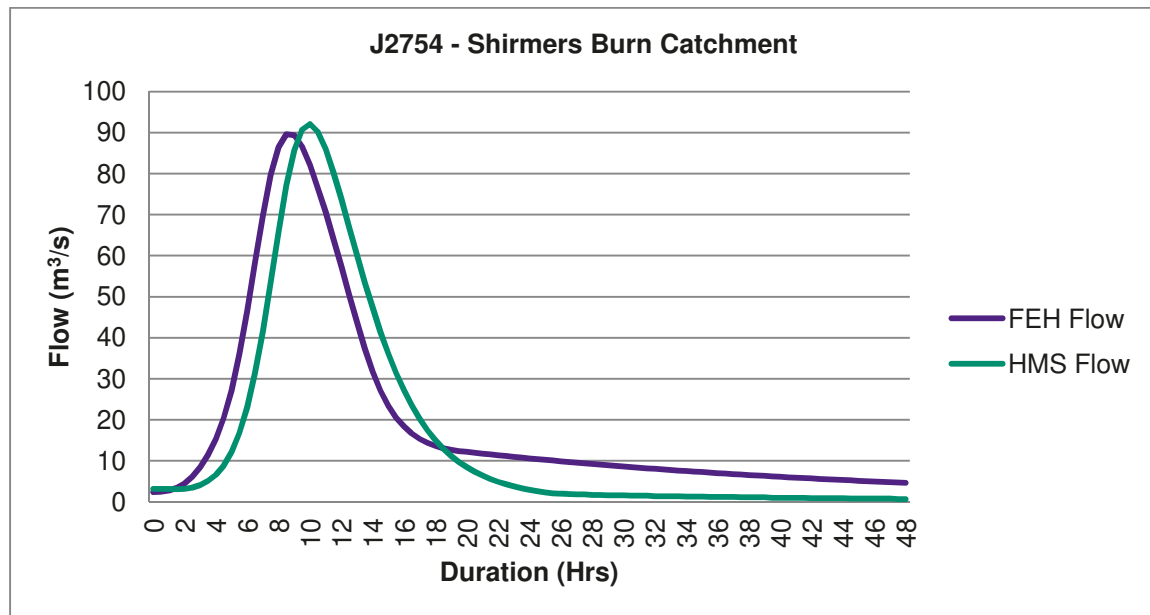


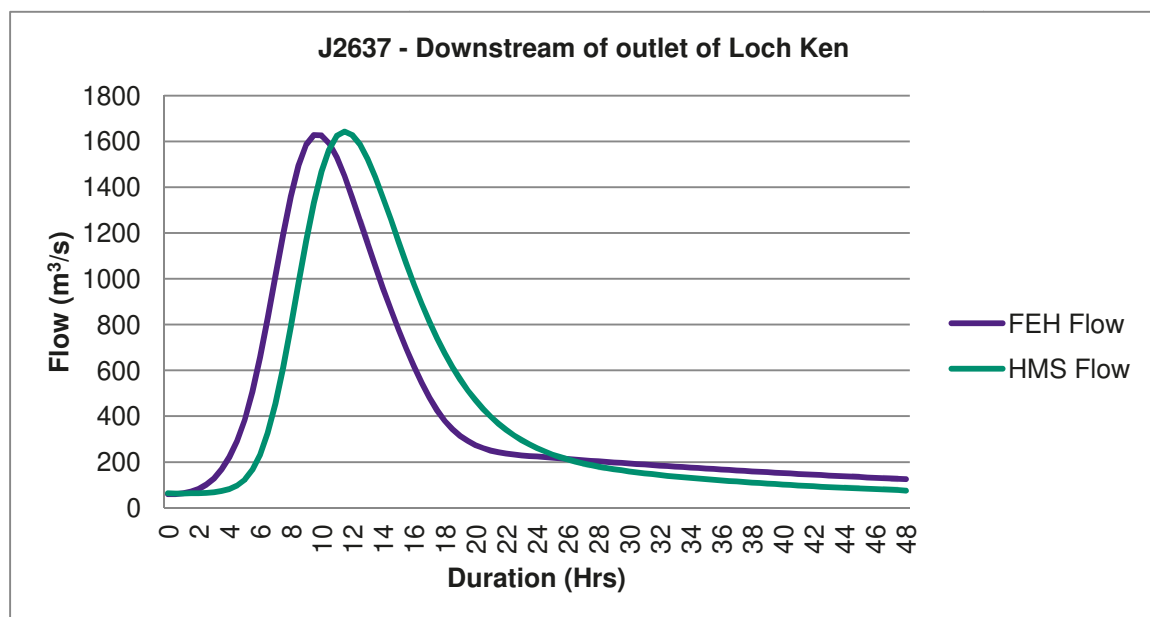
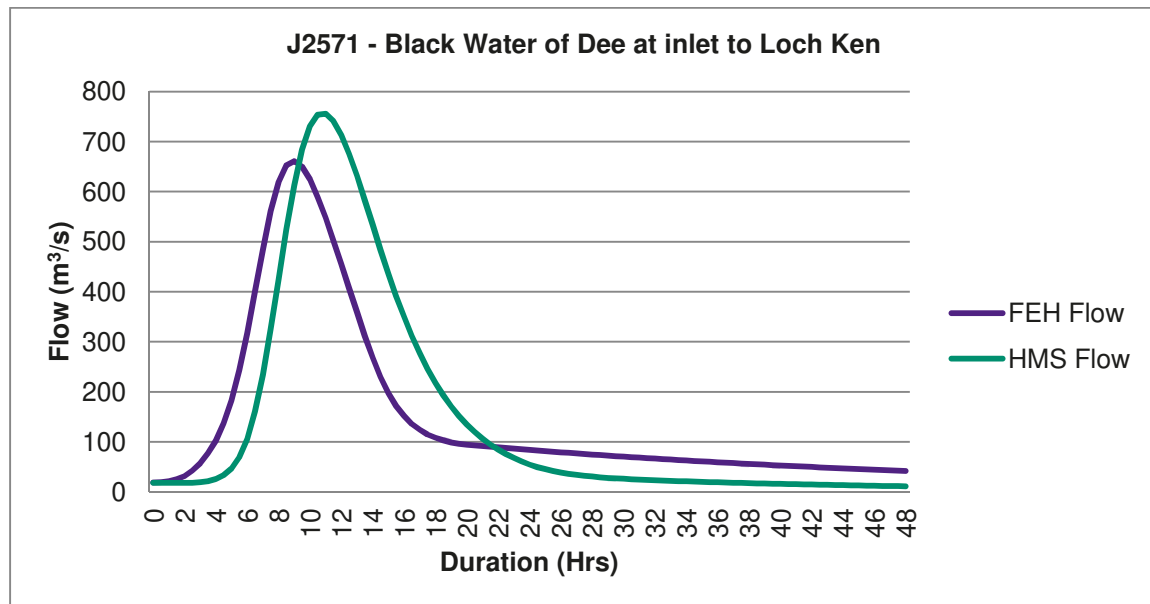
Calibration Hydrographs

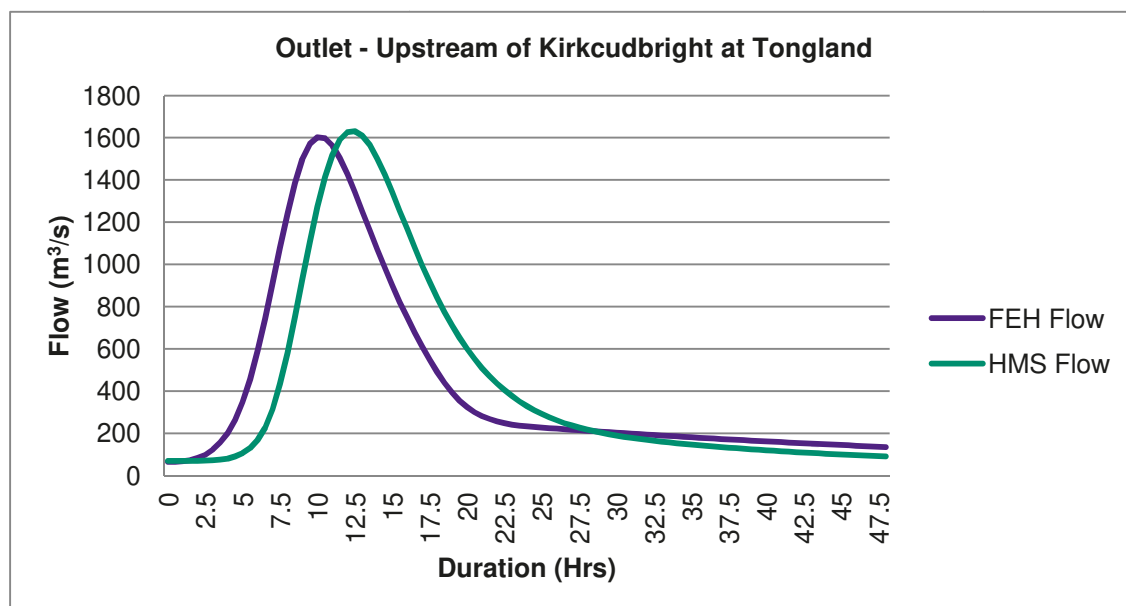
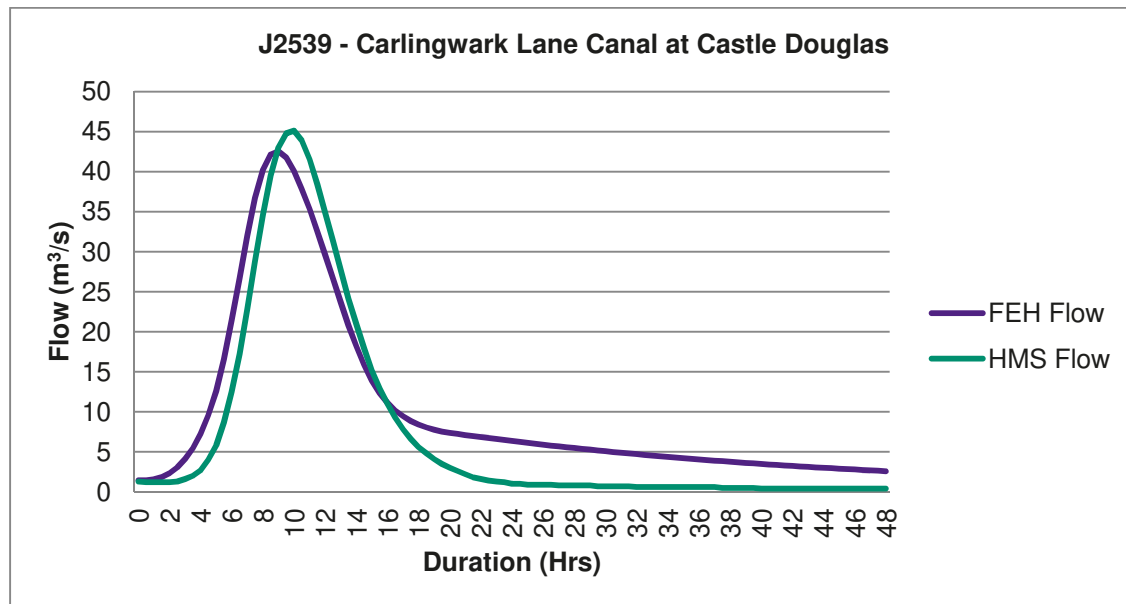
The following hydrographs illustrate the comparison between the flow hydrograph generated using the FEH methods and those produced by the HEC-HMS model at the key calibration locations within the River Dee catchment. The reference (e.g. J2613) relates to the particular node within the model representing the calibration location.











Long List Model Simulations

Table 10.2: Long List Model Simulations

Model Run No.	Compliance Point	NFM Action	NFM measures applied to Catchments	Grouped Catchments NFM measures applied to
1	Carsphairn	River Reach and Floodplain Storage	Instream Structures	38, 39, 40, 41 & 42
			Floodplain Woodland	40 & 42
			Riparian Woodland	41
			Washlands and Offline Storage Ponds	42
2	Carsphairn	Runoff Reduction	Land and Soil Management Practices	38 & 39
			Riparian Woodland	38, 39, 40 & 41
			Upland Drainage Modifications	38 & 39
			Agricultural and Upland Drainage Modifications	41 & 42
3	Carsphairn	Sediment Management	River Bank Restoration	38, 39, 41 & 42
			Overland Sediment Traps	40, 41 & 42
4	Dalry Floodplain	River Reach and Floodplain Storage	Washlands and Offline Storage Ponds	52
			Floodplain Woodland	52
5	New Galloway	River Reach and Floodplain Storage	Riparian Woodland	31
6	New Galloway	Runoff Reduction	Riparian Woodland	31
			Land and Soil Management Practices	31
			Upland Drainage Modifications	31
7	New Galloway	Sediment Management	Overland Sediment Traps	31
			River Bank Restoration	31
8	Clatteringshaws Loch	River Reach and Floodplain	Instream Structures	29, 32, 33, 34, 43, 44 & 49

Model Run No.	Compliance Point	NFM Action	NFM measures applied to Catchments	Grouped Catchments NFM measures applied to
Storage				
9	Clatteringshaws Loch	Runoff Reduction	Land and Soil Management Practices	29, 32, 33, 34, 43, 44 & 49
			Upland Drainage Modifications	29, 32, 33, 34, 43, 44 & 49
10	Clatteringshaws Loch	Sediment Management	River Bank Restoration	29, 32, 33, 34, 43, 44 & 49
11	Castle Douglas	River Reach and Floodplain Storage	Instream Structures	6, 30, 35, 36, 37, 45, 46, 47 & 48
			Washlands and Offline Storage Ponds	6
			Riparian Woodland	35 & 48
12	Castle Douglas	Runoff Reduction	Upland Drainage Modifications	6, 30, 35, 36, 37, 45, 46 & 47
			Land and Soil Management Practices	35 & 48
13	Castle Douglas	Sediment Management	River Bank Restoration	6, 30, 35, 36, 37, 45, 46 & 47
			River Morphology and Floodplain Restoration	6
			Overland Sediment Traps	35 & 48
14	Kirkcudbright	River Reach and Floodplain Storage	Instream Structures	6, 30, 35, 36, 37, 45, 46, 47 & 48
			Washlands and Offline Storage Ponds	6
			Riparian Woodland	35 & 48
15	Kirkcudbright	Runoff Reduction	Upland Drainage Modifications	6, 30, 35, 36, 37, 45, 46 & 47
			Land and Soil Management Practices	35 & 48
16	Kirkcudbright	Sediment	River Bank Restoration	6, 30, 35, 36, 37,

Model Run No.	Compliance Point	NFM Action	NFM measures applied to Catchments	Grouped Catchments NFM measures applied to
		Management		45, 46 & 47
			River Morphology and Floodplain Restoration	6
			Overland Sediment Traps	35 & 48

Long List Model Results

Table 10.3: Long List Model Results

Model Run No.	Description	Compliance Point	% Reduction in Flow for Return Period			
			1 in 2	1 in 10	1 in 50	1 in 200
1	Carsphairn: River Reach and Floodplain Storage	Carsphairn	10.3	7.8	6.2	5.2
		Dalry Floodplain	3.8	3.1	2.7	2.6
		New Galloway	3.4	2.9	2.4	2.3
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	2.0	1.6	1.1	1.2
		Kirkcudbright	1.7	1.5	1.1	1.2
2	Carsphairn: Runoff Reduction	Carsphairn	23.4	16.9	13.0	10.6
		Dalry Floodplain	6.0	4.8	4.3	3.6
		New Galloway	5.7	4.4	3.9	3.3
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	2.9	2.2	1.8	1.7
		Kirkcudbright	2.6	2.2	1.9	1.7
3	Carsphairn: Sediment Management	Carsphairn	1.5	1.6	1.6	1.3
		Dalry Floodplain	0.8	0.6	0.7	0.6
		New Galloway	0.8	0.6	0.6	0.5
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	0.6	0.3	0.1	0.4
		Kirkcudbright	0.5	0.2	0.1	0.3
4	Dalry Floodplain: River Reach and Floodplain Storage	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.6	0.6	0.4	0.4
		New Galloway	0.6	0.5	0.4	0.4
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	0.4	0.5	0.3	0.3
		Kirkcudbright	0.3	0.3	0.4	0.2
5	New Galloway: River Reach and Floodplain Storage	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	2.0	1.3	0.0	0.7
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	0.0	0.0	0.0	0.0
		Kirkcudbright	0.0	0.0	0.0	0.0

Model Run No.	Description	Compliance Point	% Reduction in Flow for Return Period			
			1 in 2	1 in 10	1 in 50	1 in 200
6	New Galloway: Runoff Reduction	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	7.8	6.6	4.6	4.1
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	0.1	0.1	0.0	0.0
		Kirkcudbright	0.1	0.1	0.0	0.0
7	New Galloway: Sediment Management	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	2.0	1.3	0.9	0.7
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	0.0	0.0	0.0	0.0
		Kirkcudbright	0.0	0.0	0.0	0.0
8	Clatteringshaws Loch: River Reach and Floodplain Storage	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	0.0	0.0	0.0	0.0
		Clatteringshaws Loch	3.3	1.1	1.4	2.4
		Castle Douglas	0.6	0.4	0.1	0.4
		Kirkcudbright	0.6	0.3	0.2	0.3
9	Clatteringshaws Loch: Runoff Reduction	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	0.0	0.0	0.0	0.0
		Clatteringshaws Loch	16.7	9.8	7.5	7.1
		Castle Douglas	2.8	1.9	1.1	1.1
		Kirkcudbright	2.6	1.8	1.2	1.1
10	Clatteringshaws Loch: Sediment Management	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	0.0	0.0	0.0	0.0
		Clatteringshaws Loch	2.5	0.5	0.8	1.3
		Castle Douglas	0.4	0.2	0.2	0.2
		Kirkcudbright	0.4	0.1	0.3	0.1
11	Castle Douglas: River Reach and Floodplain Storage	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	0.0	0.0	0.0	0.0

Model Run No.	Description	Compliance Point	% Reduction in Flow for Return Period			
			1 in 2	1 in 10	1 in 50	1 in 200
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	1.0	1.2	0.6	1.2
		Kirkcudbright	0.8	0.9	0.6	1.1
12	Castle Douglas: Runoff Reduction	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	0.0	0.0	0.0	0.0
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	1.2	1.4	0.7	1.2
		Kirkcudbright	0.9	1.0	0.7	1.1
13	Castle Douglas: Sediment Management	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	0.0	0.0	0.0	0.0
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	1.4	1.7	1.0	1.4
		Kirkcudbright	1.3	1.3	1.0	1.4
14	Kirkcudbright: River Reach and Floodplain Storage	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	0.0	0.0	0.0	0.0
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	1.0	1.2	0.6	1.2
		Kirkcudbright	0.8	0.9	0.6	1.1
15	Kirkcudbright: Runoff Reduction	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	0.0	0.0	0.0	0.0
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	1.2	1.4	0.7	1.2
		Kirkcudbright	0.9	1.0	0.7	1.1
16	Kirkcudbright: Sediment Management	Carsphairn	0.0	0.0	0.0	0.0
		Dalry Floodplain	0.0	0.0	0.0	0.0
		New Galloway	0.0	0.0	0.0	0.0
		Clatteringshaws Loch	0.0	0.0	0.0	0.0
		Castle Douglas	1.4	1.7	1.0	1.4
		Kirkcudbright	1.3	1.3	1.0	1.4

Appendix F – Site Reconnaissance Surveys

1. Site Reconnaissance Surveys

This appendix presents the results of the reconnaissance surveys to provide supporting information for the Galloway Glens Natural Flood Management scoping study. Data collected allow the feasibility of short listed options to be put into context with environmental conditions.

The key areas were surveyed:

- Carsphairn – the catchments upstream of the receptor have been split into 5 distinct areas where natural flood management has been identified as presented in Figure GB11820_M_014. Section 2 presents the results of the surveys at Carsphairn;
- New Galloway – the catchment of the Mill Burn is the primary tributary that encompasses New Galloway. The site reconnaissance surveys were carried out within areas upstream of the receptor and focussed on the NFM measures outlined in Figure GB1180_M_015. Section 3 presents the results of the surveys at New Galloway.

2. Carsphairn

2.1. Carsphairn Area 1

SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	1A

WEATHER DETAILS

During Site Visit:	Cold, 6 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

1A – Upper Garryhorn Burn Overview

Photos of upper catchment. Looking south through south west from marker point.

Observations;

- Upland catchment comprising open heathland and grassland.
- Larger channels incised into glacial deposits, unless in steeper ground where incised into bedrock
- Smaller channels often incised into peat with a few not being visible at all. These ephemeral channels are likely to move locations quickly making in-channel modification potentially problematic. Closer inspection would be required to determine feasibility
- Apart from the higher ground extensive areas have been artificially drained with vertical ditches dug into the peat

Additional Note – vehicular access is very good to this location

PHOTOGRAPH LOCATION

Grid Reference – NX 53254 93665 (*Blue marker denotes location*)



SURVEY PHOTOGRAPHS (1A)



SURVEY PHOTOGRAPHS (1A)



SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	1B

WEATHER DETAILS

During Site Visit:	Cold, 6 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

1B – Garryhorn Burn Tributary

Photos of immediate catchment and channel morphology

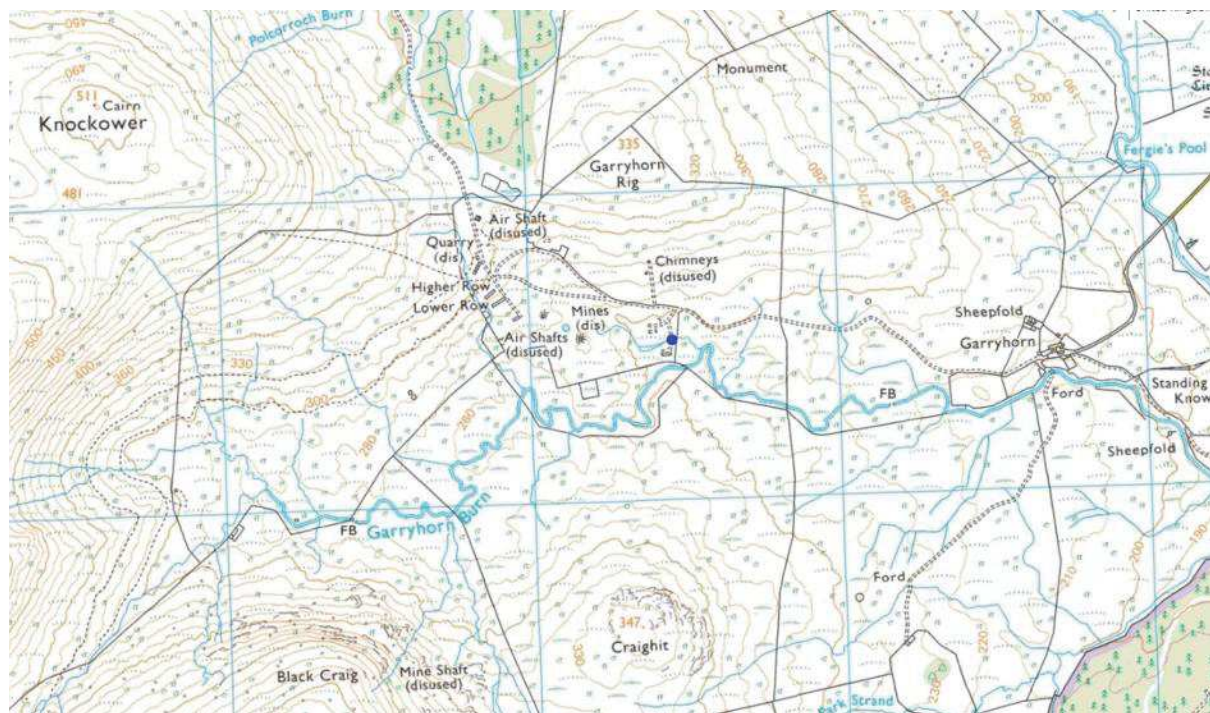
Observations:

- Shallow channel slope <5 degrees with very slow flow
- Upstream appears engineered / disturbed by mine workings
- Lots of small gravel bars, falls and pools within mine workings
- Bed material a mixture of boulders, gravel and sand with rocky banks
- Where stream isn't in workings channel is narrower and very vegetated and flowing through boggy areas
- Banks are rocky inside workings and grass and peat outside
- Stream width 0.2m to 3m with depth varying but predominantly shallow

Additional Note – vehicular access is very good to this location

PHOTOGRAPH LOCATION

Grid Reference –NX 53466 93510 (*Blue marker denotes location*)



SURVEY PHOTOGRAPHS (1B)



SURVEY PHOTOGRAPHS (1B)



SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	1C

WEATHER DETAILS

During Site Visit:	Cold, 6 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

1C – Garryhorn Burn

Photos of immediate catchment and channel morphology

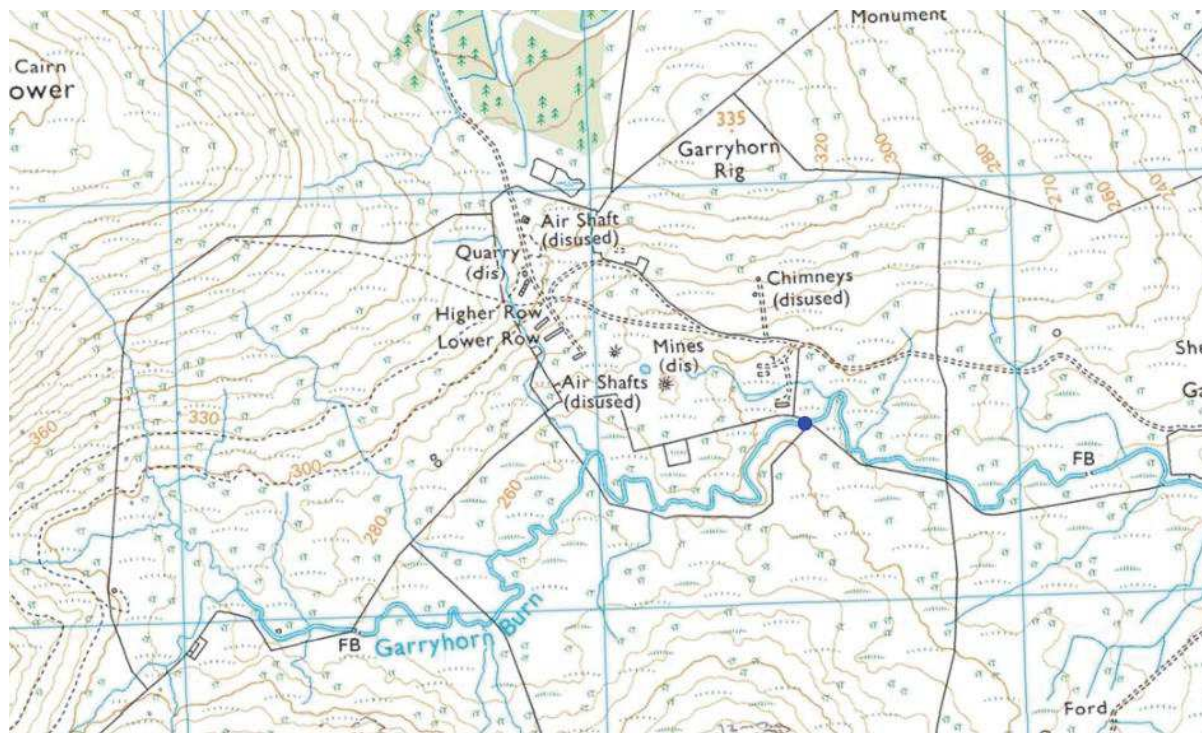
Observations:

- Channel slope is ~5 degrees with a moderate flow speed
- Channel is slightly sinuous and is incised into surrounding peat /soil. In the upper catchment above this point that channel has current terraces down into the glacial deposits
- Gravel bars often situated on the inside of meanders with occasional braided sections on flatter ground. Some evidence of bank collapse
- Bed material is gravel, cobbles and boulders with a lot of boulders protruding the water surface. Finer sediments situated in lower flow areas
- Banks are predominantly grassy however can be rockier on the inside of meanders
- Stream width is ~10m and is generally shallow

Additional Note – vehicular access is very good to this location

PHOTOGRAPH LOCATION

Grid Reference –NX 53468 93441 (*Blue marker denotes location*)



SURVEY PHOTOGRAPHS (1C)





SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	1D

WEATHER DETAILS

During Site Visit:	Cold, 6 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

1D – Garryhorn Burn and Mine Workings Overview

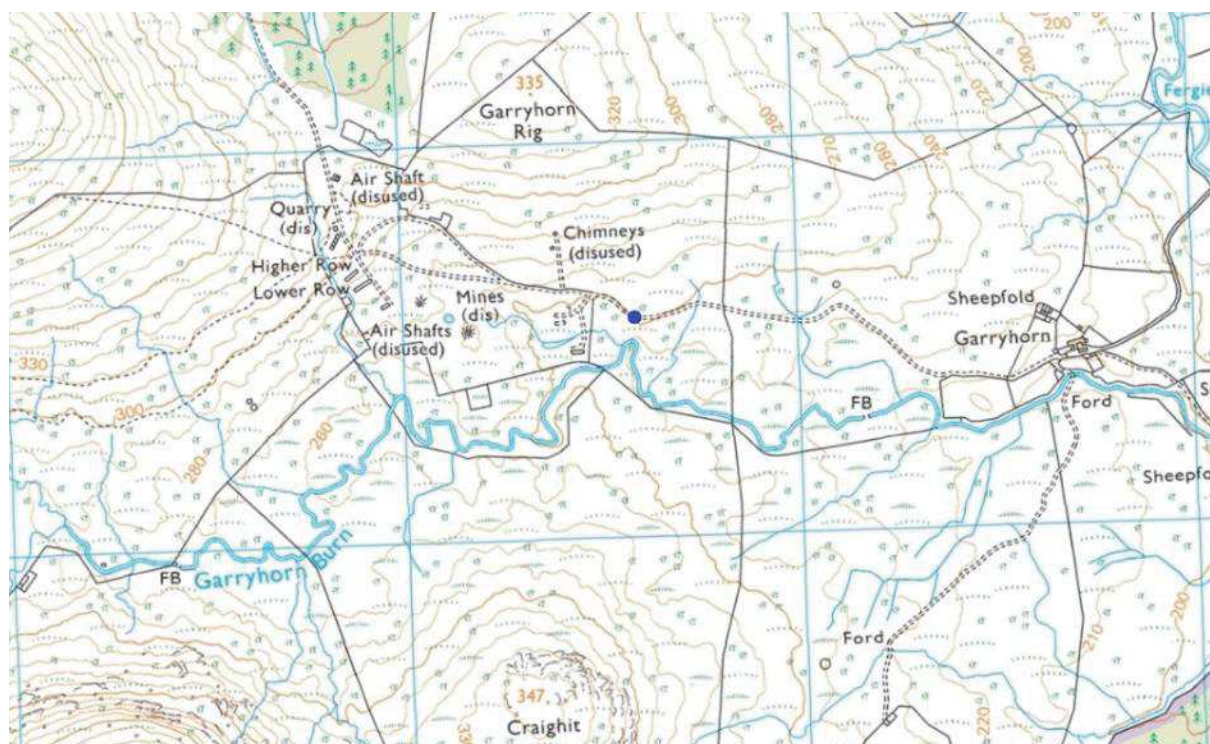
Photos of mine workings and upper catchment

Observations:

- Mine workings have influenced available bedload material such as gravels and finer sediments. Channels are rockier with channels themselves being poorly defined on flatter ground
- Main burn appears to be incised into late glacial deposits, with steep banks leading down to river terraces where the channel has laterally migrated and back filled. Good location for riparian woodland

PHOTOGRAPH LOCATION

Grid Reference –NX 53585 93557 (*Blue marker denotes location*)



SURVEY PHOTOGRAPHS (1D)



SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	1E

WEATHER DETAILS

During Site Visit:	Cold, 6 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

1E – Garryburn Main Channel

Photos of immediate catchment and channel morphology

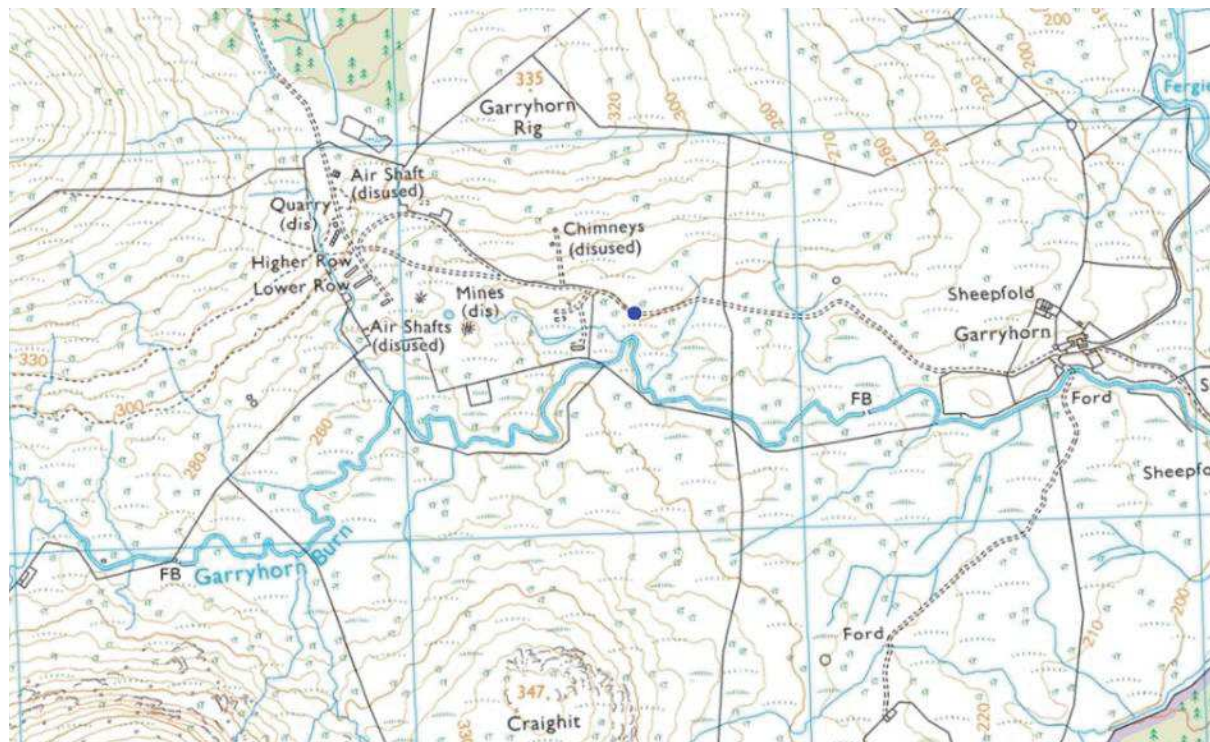
Observations

- Channel slope ~5 degrees with a moderate flow speed
- Sinuous with meanders
- Minor depositional gravel bars on inside banks
- Banks incised into peat/ till and have collapsed into channel in some locations
- Bed material is boulders, cobbles and gravel
- Banks are grassy / peat. Very water logged
- Width 3-4 m and generally shallow

Additional Note – vehicular access is very good to this location

PHOTOGRAPH LOCATION

Grid Reference –NX 53609 935502 (*Blue marker denotes location*)



SURVEY PHOTOGRAPHS (1E)



SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	1F

WEATHER DETAILS

During Site Visit:	Cold, 6 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

1F – Garryhorn Burn

Photos of flat areas north of the Burn looking over towards areas considered for LMPs

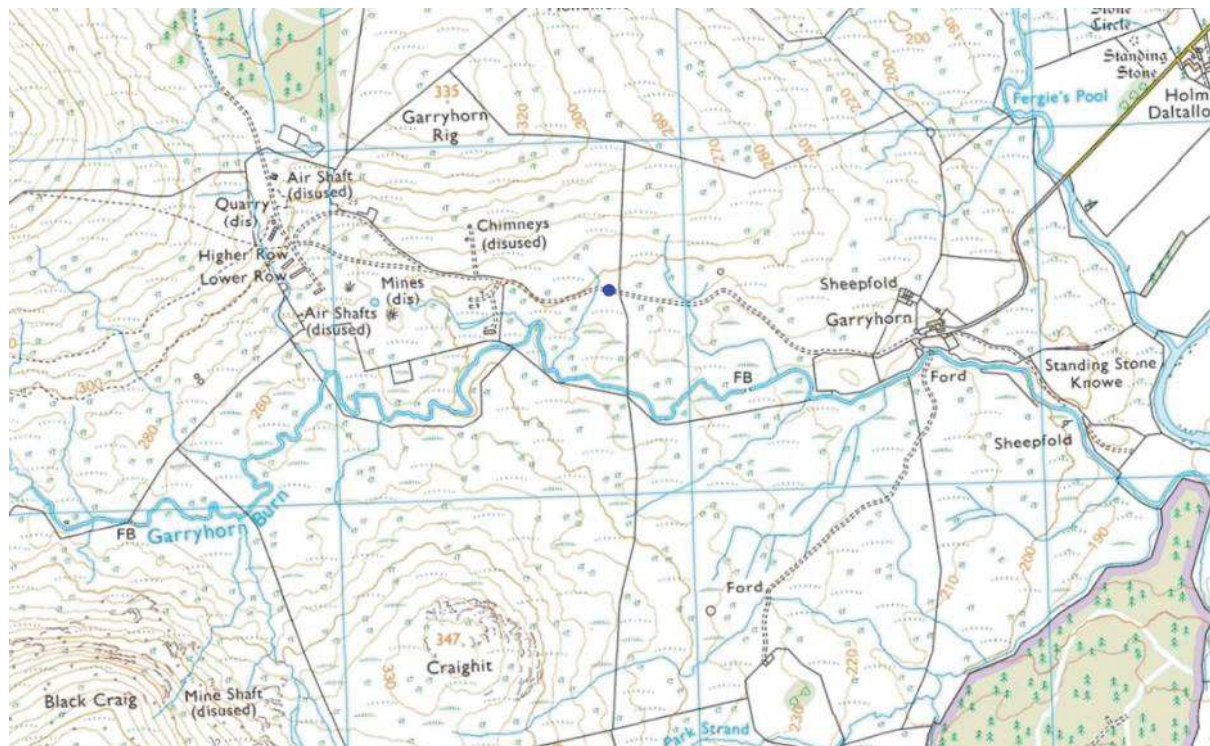
Observations:

- Area is very tussocks with a few patches of grazed grasslands
- Very water logged where flat
- Evidence of land draining also seen to the south west with numerous narrow linear ditches discharging towards the main channel

Additional Note – vehicular access is very good to this location

PHOTOGRAPH LOCATION

Grid Reference –NX 53772 93580 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (1F)



SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	1G

WEATHER DETAILS

During Site Visit:	Cold, 6 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

1G – Garryhorn Burn River Terrace Area

Photos of flat and level ground below track just above the main burn

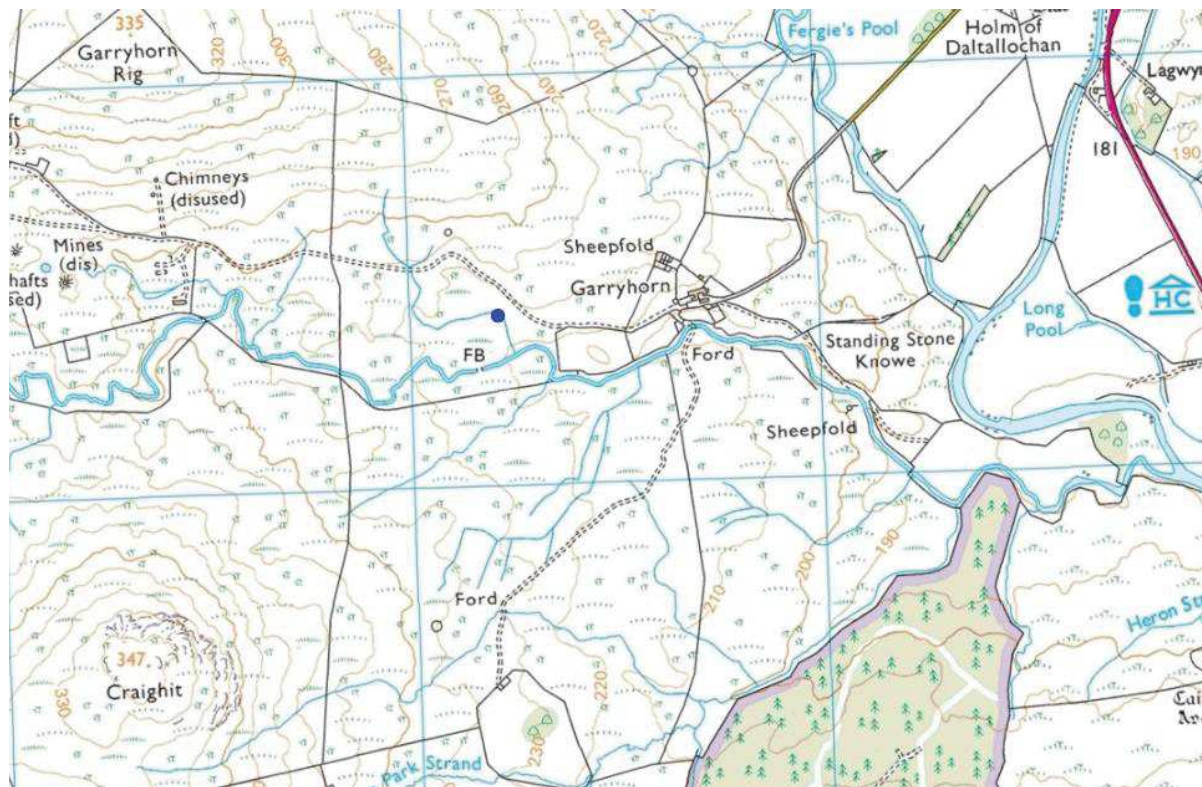
Observations:

- Linear artificial land drainage channels cut into the peat on level, boggy ground close to main channel
- 0.4-0.6m deep & 0.2-0.4 m wide with a very slow flow
- Very shallow channel angle <5 degrees
- Silt/ peat bedload with banks being tussocks and bog

Additional Note – vehicular access is very good to this location

PHOTOGRAPH LOCATION

Grid Reference –NX 54229 93406 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (1G)





SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	1H

WEATHER DETAILS

During Site Visit:	Cold, 6 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

1H – Garryhorn Burn

Photos of immediate catchment and channel morphology

Observations:

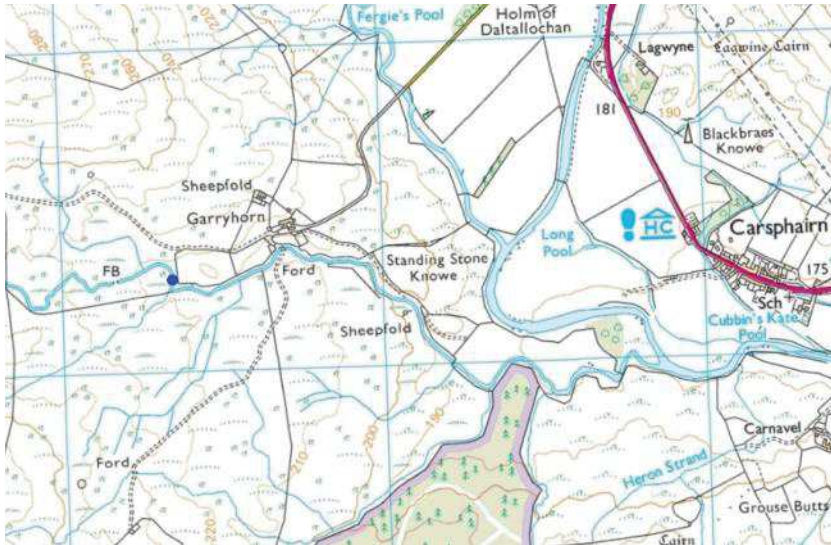
- Channel slope upstream is ~5 degrees and moderate flow speed with slope increasing ~5-10 degrees downstream with moderate to fast flow
- Upstream the channel is more level and sinuous and downstream becomes steeper and more linear
- Upstream
 - Bedload cobbles and boulders with some gravel bars in lower flow areas and is slightly sinuous
 - Additional exposed terrace deposits on meanders suggest channel regularly migrates
 - Banks are vegetated (peat, grass with some trees) and are comprised of soil / gravels
 - Very boggy upstream of location
- Downstream
 - Bedload is limited due to exposed bedrock, with cobbles and boulders being caught in plunge pools and low flow areas etc
 - Banks are on bedrock and grass with thin soils
 - Banks are covered with numerous trees which are more extensive than upstream in flatter areas
- Channel is ~7m wide while flowing through river terraces, but is narrower ~5m downstream where incised into bedrock

Additional Note – vehicular access is very good to this location

PHOTOGRAPH LOCATION

Grid Reference –NX 54323 93338 (*Blue marker denotes location*)

SURVEY DETAILS



SURVEY PHOTOGRAPHS (1H)



SURVEY DETAILS



SURVEY DETAILS



SURVEY DETAILS



SURVEY DETAILS



2.2. Carsphairn Area 2

SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	2A

WEATHER DETAILS

During Site Visit:	Cold, 9 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

2A – Upper Water of Deugh

Photos of immediate catchment and channel morphology

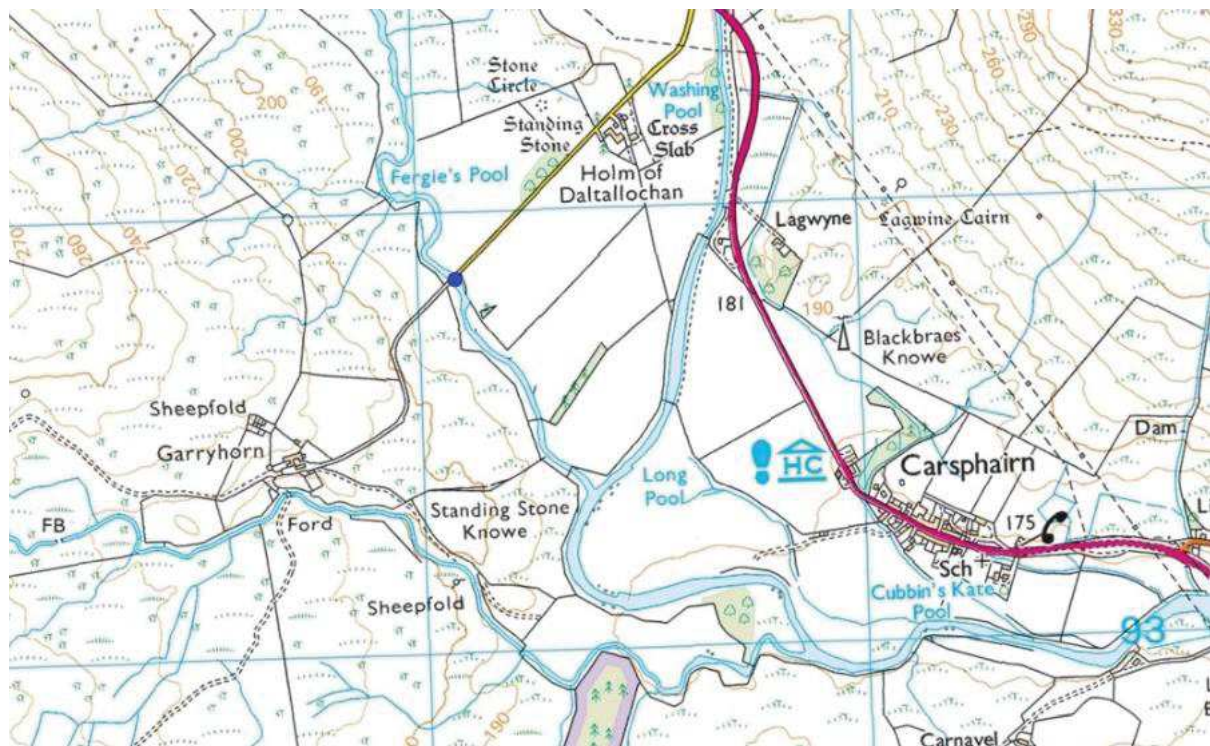
Observations:

- Channel slope very low ~2-5 degrees with a slow flow
- Channel is sinuous and meandering
- Bedload is silt and sand with some gravels
- Very few boulders protruding water surface
- Banks are vegetated and occasionally tree lined. Combination of soil and peat. Wide and flat
- Nearby slopes often artificially drained by vertical drainage channels. Channels are incised into the peat

Additional Note – vehicular access is good to this location

PHOTOGRAPH LOCATION

Grid Reference –NX 55080 93833 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (2A)







SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	2B

WEATHER DETAILS

During Site Visit:	Cold, 9 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

2B – Upper Water of Deugh (aka Carsphain Lane)

Photos of catchment. Looking south through south west from location

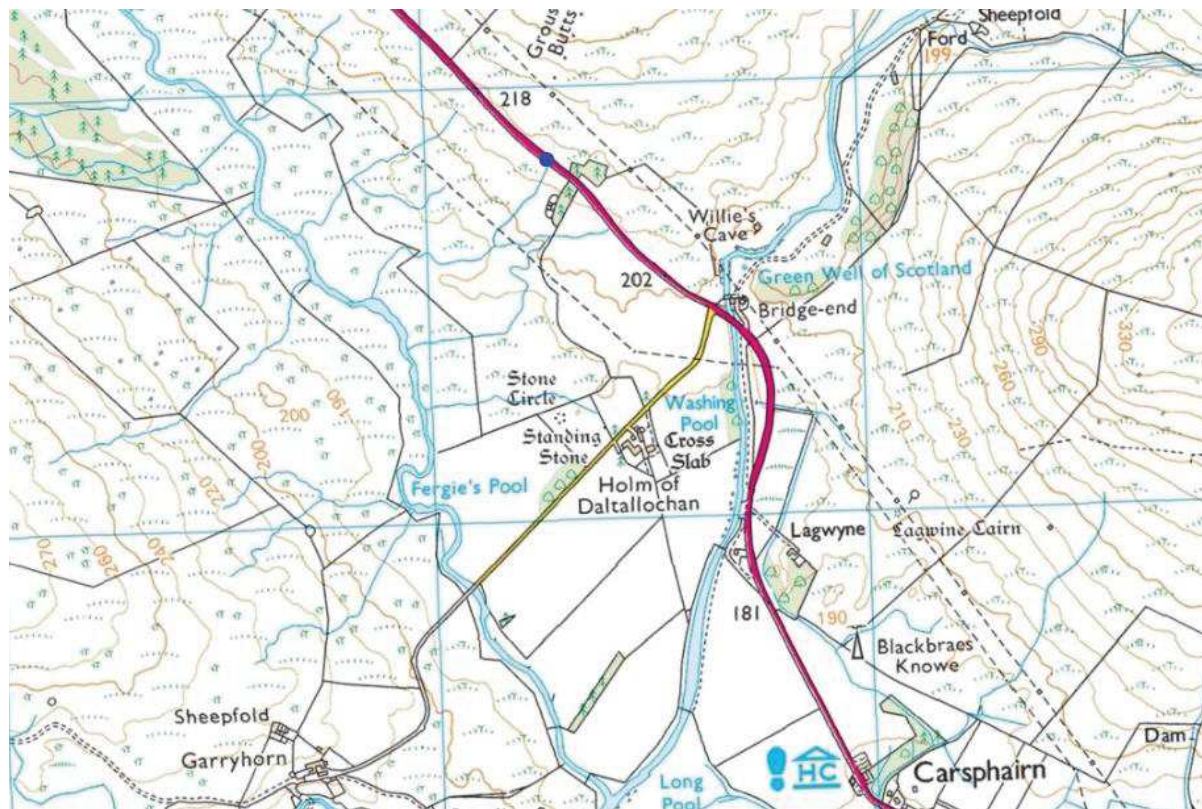
Observations:

- Area contains sinuous channel ~15m wide
- Banks appear to be gassy and boggy with some small trees dotting the base of the valley
- Extensively flat and terraced with a lot of water saturated ground
- Slopes above to the SW are grassy with some tussocks. Looks suitable for hedgerows, burrows etc.

Additional Note – vehicular access down to the river is very poor, with very wet and boggy ground

PHOTOGRAPH LOCATION

Grid Reference –NX 55231 94873 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (2B)





SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	2C

WEATHER DETAILS

During Site Visit:	Cold, 9 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

2C – Carsphairn Lane (river just east of Loch Doon)

Photos of immediate catchment and channel morphology

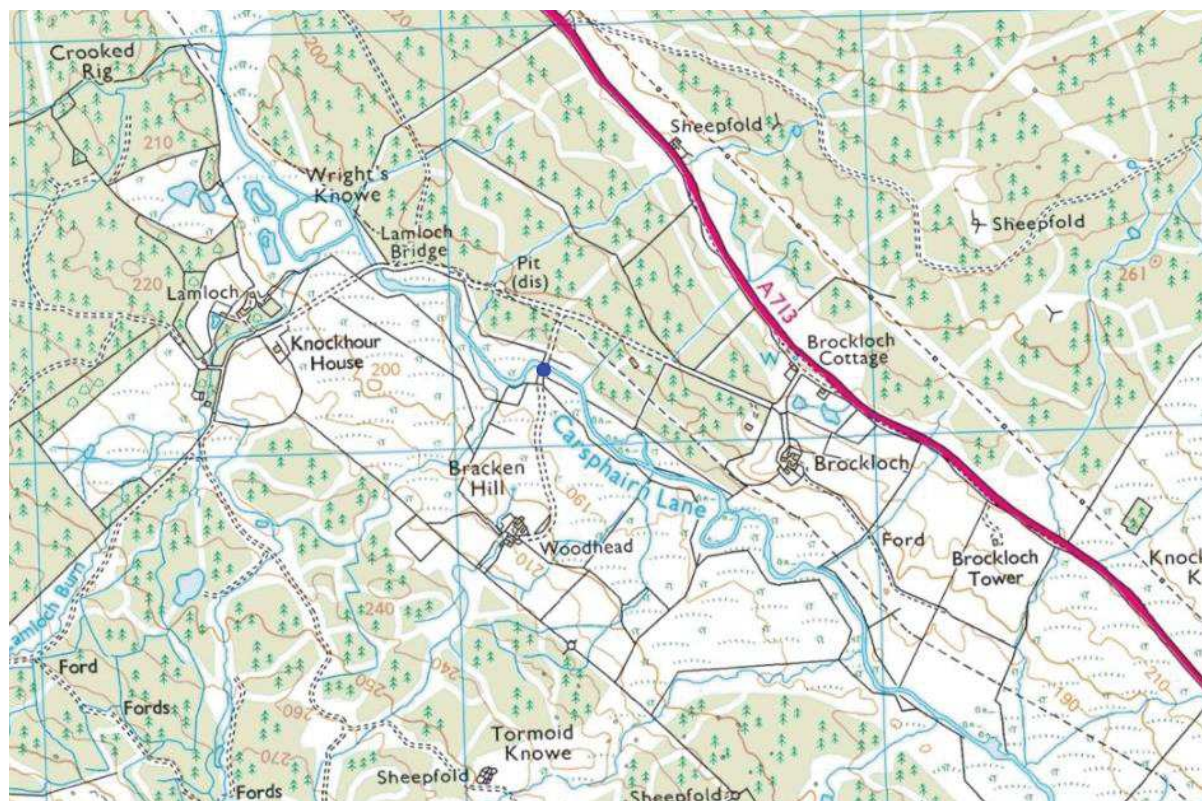
Observations:

- Low channel slope, less than 5 degrees with very slow flow
- Channel is sinuous and is incised into peat / gravel soil. More extensive gravels on inside of meanders. Some bank protection engineered around bridge
- Bedload comprises of boulders, cobbles and gravels, some of which protrude the water surface
- Banks are flat and level and generally grassed

Additional Note – vehicular access is reasonable at this location

PHOTOGRAPH LOCATION

Grid Reference –NX 53216 961159 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (2C)





2.3. Carsphairn Area 3

SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	3A

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

3A – Water of Deugh

Photos of immediate catchment and channel morphology

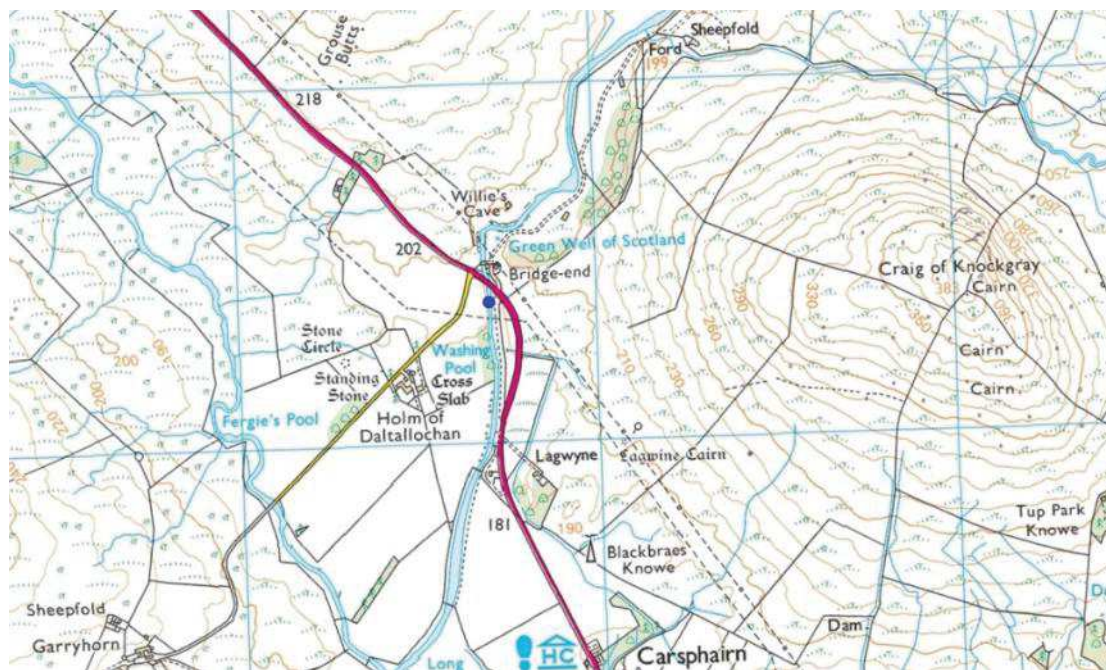
Observations;

- Channel slope is between 5-10 degrees with a moderate flow speed
- Channel incised into bedrock with steep bedrock and soil banks
- Channel 10-15m wide and 0.2-1m deep
- Bedload of gravels, cobbles and boulders with pools and falls. Boulders protruding through water surface
- Banks are generally tree and grass lined
- Road and track drainage appears to discharge into the river
- Storm debris washed into tree ~1-2m above current river level
- Some bank engineering around the bridge

Additional Note – bankside vehicular access is good at this location

PHOTOGRAPH LOCATION

Grid Reference –NX 55729 94395 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (3A)





SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	3B

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

3B – Water of Deugh

Photos of immediate catchment and channel morphology

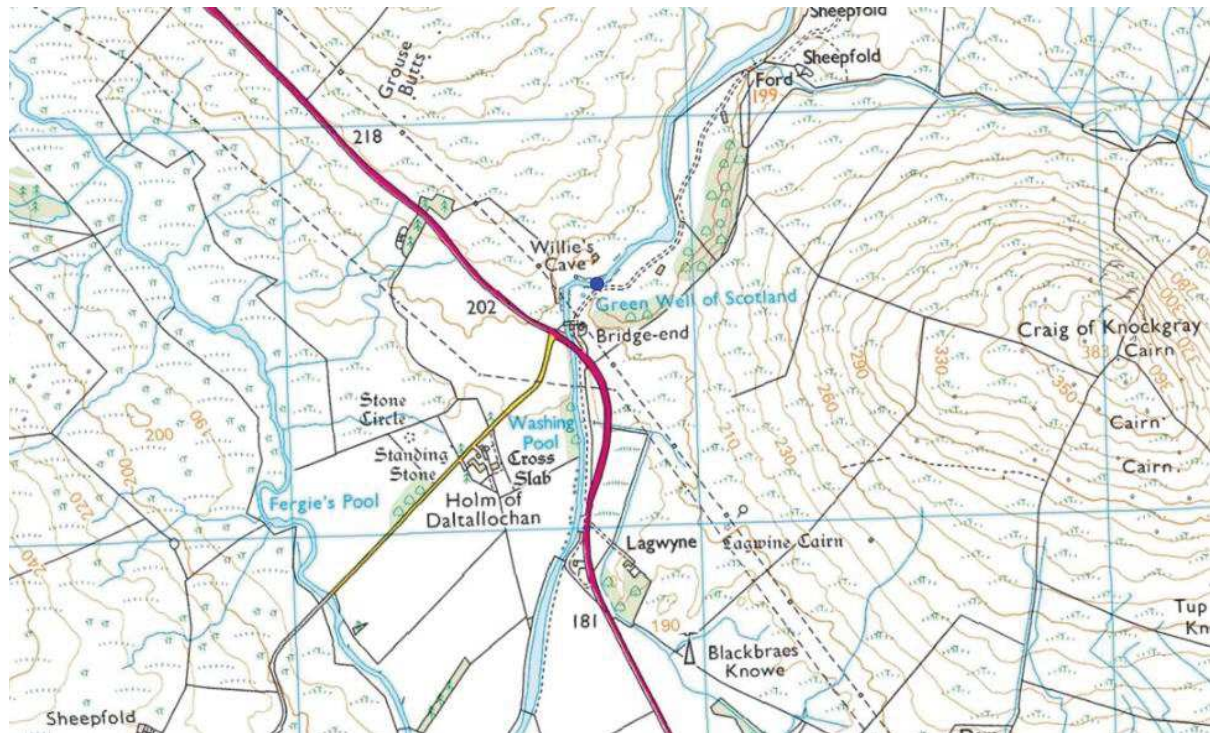
Observations:

- Channel slope ~5-10 degrees with a moderate to fast flow.
- Gorge like morphology with plunge pools and falls with channel incised into bedrock with large sections of bedrock base protruding water surface
- Channel 10m wide with depths varying due to plunge pools and falls
- Bedload is predominantly cobbles and boulders
- Banks are bedrock and boulders with grass and soil. Tree higher up intermittently lining the bank
- Lots of artificial and drainage into stream reducing water logging in the surrounding soil
- Channel appears to be more meandering just up stream. Again evidence of very high flow volumes with debris 2-3m above current channel level

Additional Note – bankside vehicular access is good at this location

PHOTOGRAPH LOCATION

Grid Reference –NX 55766 94577 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (3B)





SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	3C

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

3C – Water of Deugh

Photos of immediate catchment and channel morphology

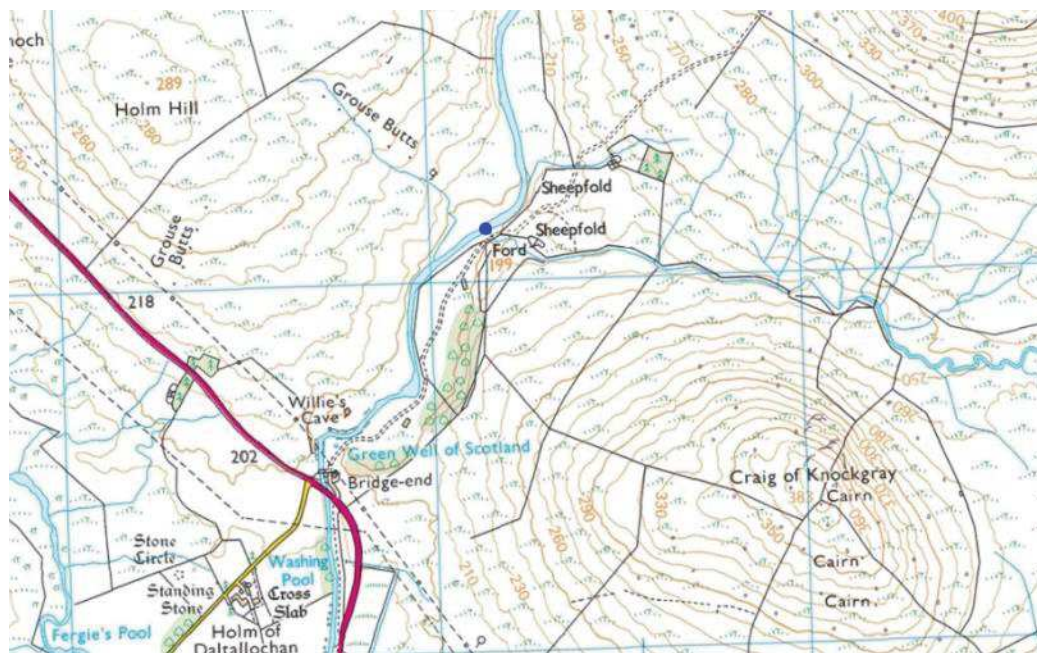
Observations:

- Main channel has a slope of 5 degrees with a high to moderate flow speed
- Channel is braided with sequences of gravels, cobbles and boulders
- Channel has a very high sediment yield with gravel banks and bars and is incised only on river bend outside banks
- Channel is 7m wide with braided area being 25m in diameter
- Banks are grass, soil and gravel however significant erosion and bank collapse is happening in some places (see photos)
- Recent engineering work around track for stabilisation and protection
- Location possibly more suited to riparian woodland as opposed to floodplain woodland?
- Catchment hill slopes are steeper closer to the river (where note terraced) but predominantly gently sloping. Visible vertical drainage ditches which are likely to be artificial

Additional Note – bankside vehicular access is good at this location. Far bank may be more complicated.

PHOTOGRAPH LOCATION

Grid Reference –NX 56150 95094 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (3C)







SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	3D

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

3D – Benloch Burn (Water of Deugh tributary)

Photos of immediate catchment and channel morphology

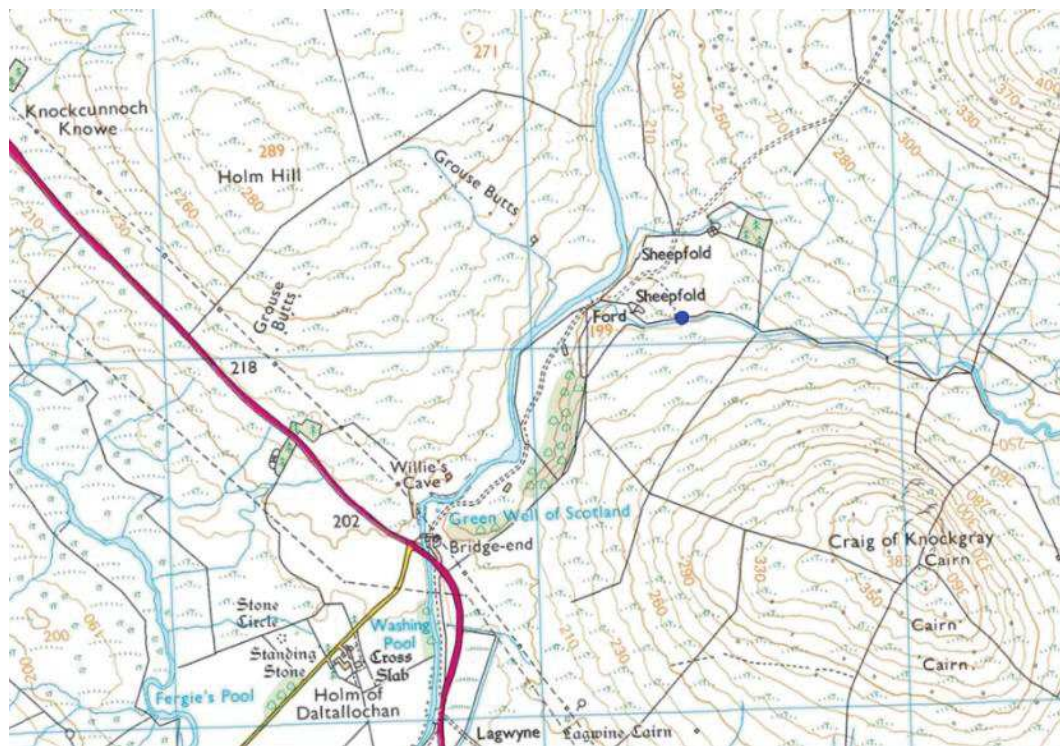
Observation;

- Channel slope is between 5-10 degrees with a moderate flow rate
- Channel morphology varies between small sinuous / braided deposits to falls and plunge pools
- Bedload varies between gravels and solid bedrock
- Channel is deeply incised into bedrock with steep banks in some locations but is only incised into the peat in others and is more sinuous
- Banks are bedrock or soil / peat and in steeper sections contain small trees
- Evidence of widespread artificial drainage on slope to west with vertical ditches running the length of the hill side
- Localised bog draining closer to the channel on northern side as well

Additional Note – bankside vehicular access is poor at this location

PHOTOGRAPH LOCATION

Grid Reference –NX 56323 95050 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (3D)







SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	3E

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

3E – Upper Deugh and Benloch Overview

Photos of upper catchments, looking north and west

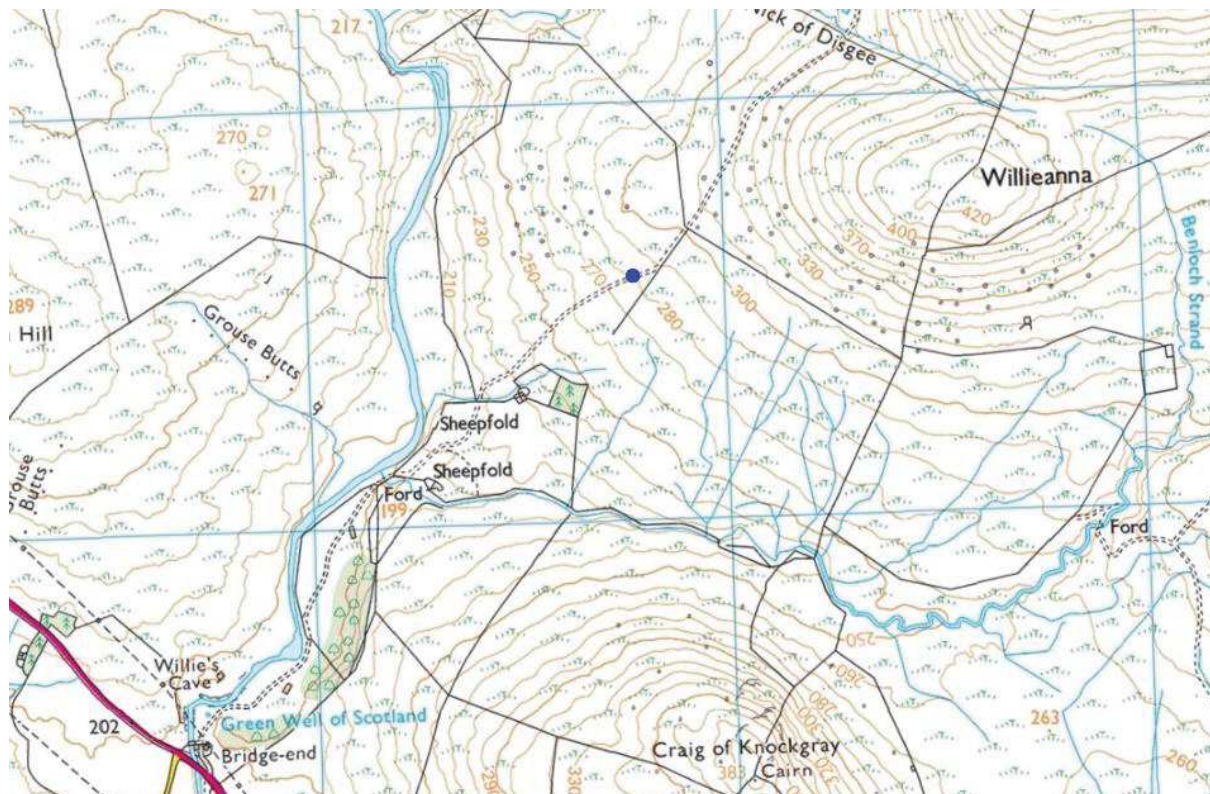
Observations:

- Ground is grazed grassland with some scree and tussocks and are probably only suitable for hedgerow planting 250m elevation due to the exposed nature of the hill side
- Areas of bog have been vertical artificial drained using ditches. These extend across most hillsides
- Many of the channels identified for in channel modification are small and incised into the peat / soil and are characterised by falls and plunge pools. Some are also ephemeral and would be difficult to locate.

Additional Note – vehicular access is very good to this location but the track deteriorates further uphill.

PHOTOGRAPH LOCATION

Grid Reference –NX 56323 95050 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (3E)





2.4. Carsphairn Area 4

SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	4A

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

4A – Lamford Burn

Photos of immediate catchment and channel morphology

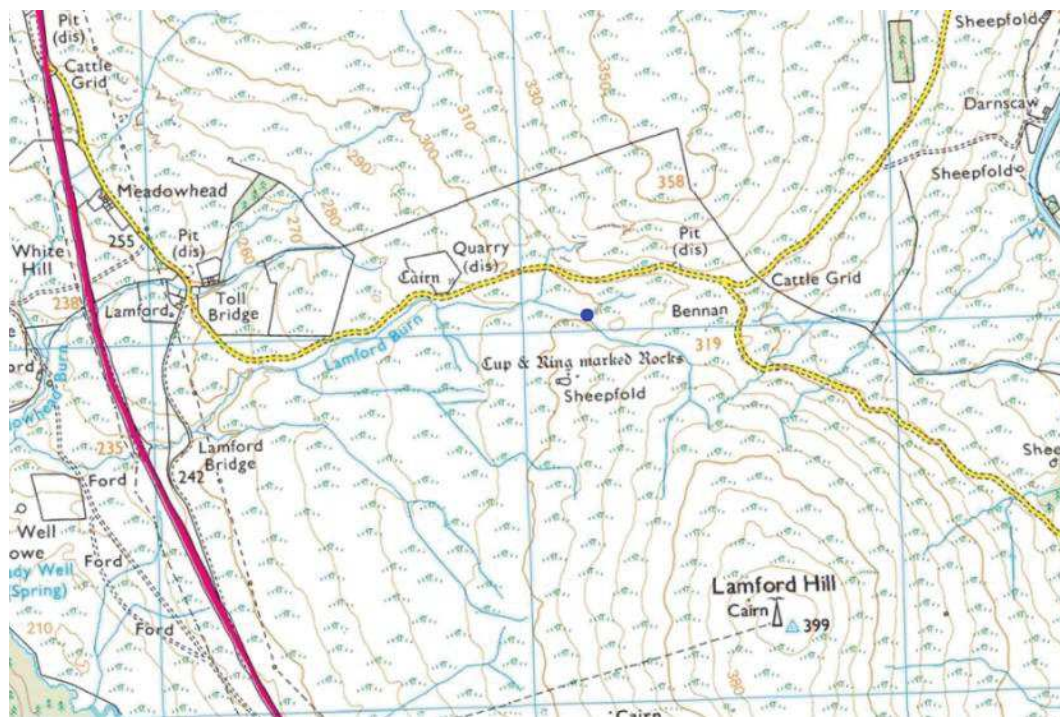
Observations;

- Narrow upland channel with a slope of 5-10 degrees which is incised into the peat and tussocks. Flow speed is moderate
- Bedload is a mix of sand and gravel which is heavily silted and discoloured by the peat
- Channel is ~0.3-0.5m wide and of similar depth with plunge pools and small falls
- Banks are grass tussocks

Additional Note – bankside vehicular access is reasonable at this location

PHOTOGRAPH LOCATION

Grid Reference –NX 53020 99083 (*Blue marker denotes location*)



SURVEY PHOTOGRAPHS (4A)





SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	4B

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

4B – Lower Lamford Burn

Photos of immediate catchment and channel morphology

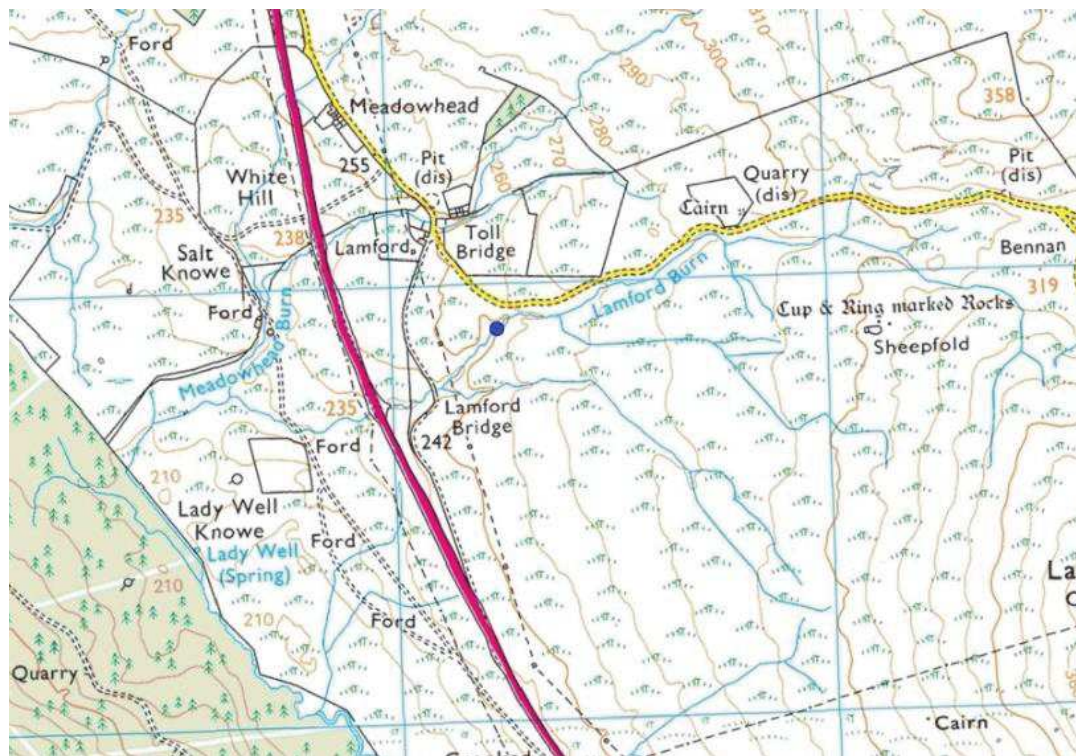
Observations:

- Channel slope ~20-25 degrees with a fast to moderate flow speed
- Channel morphology is gorge like and is deeply incised into bedrock / glacial sediments to ~10m, with grass growing most of the way down to the channel
- Channel is falls and plunge pools and becomes more sinuous further downstream
- Bedload comprises mainly of solid bedrock with cobbles and boulders in plunge pools
- Banks are mainly steep grass with protrusions of bed rock
- Channel is ~0.1 to 0.5m wide with depth varying due to runs and pools
- Suitable location for tree planting

Additional Note – bankside vehicular access is good at this location

PHOTOGRAPH LOCATION

Grid Reference –NX 53020 99083 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (4B)





2.5. Carsphairn Area 5

SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	5A

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

5A – Dun Hill & Craignane (Windy Standard)

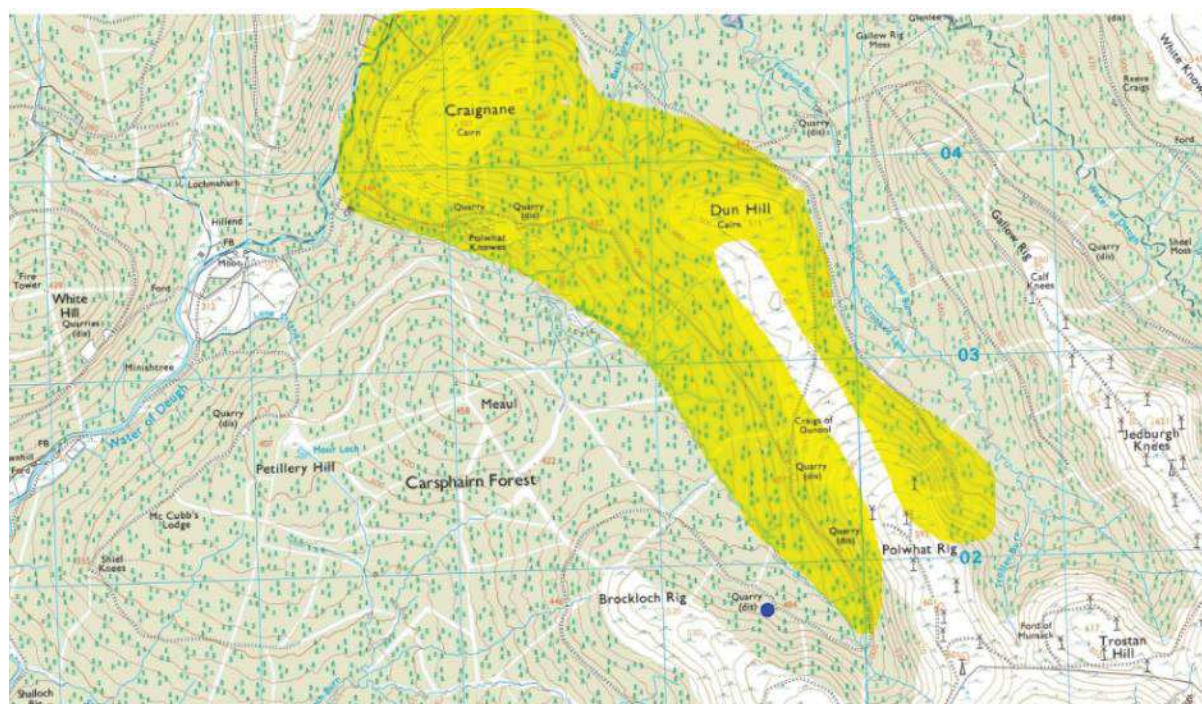
Photos of proposed locations, looking north from access track

Observations;

- Photo vantage point of cleared forest west of Polwat Rig
- Forest has been cleared in locations marked with some minor regrowth
- Conversations with on-Site personnel eluded to the fact that many of the smaller channels are likely to already contain logs, branches etc

PHOTOGRAPH LOCATION

Grid Reference –NS 59543 01776 (Blue marker denotes location. Yellow highlights mark observed locations and confirm the extent of deforestation)



SURVEY PHOTOGRAPHS (5A)





SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	5B

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

5B – Waterhead Hill & Meaul (Windy Standard)

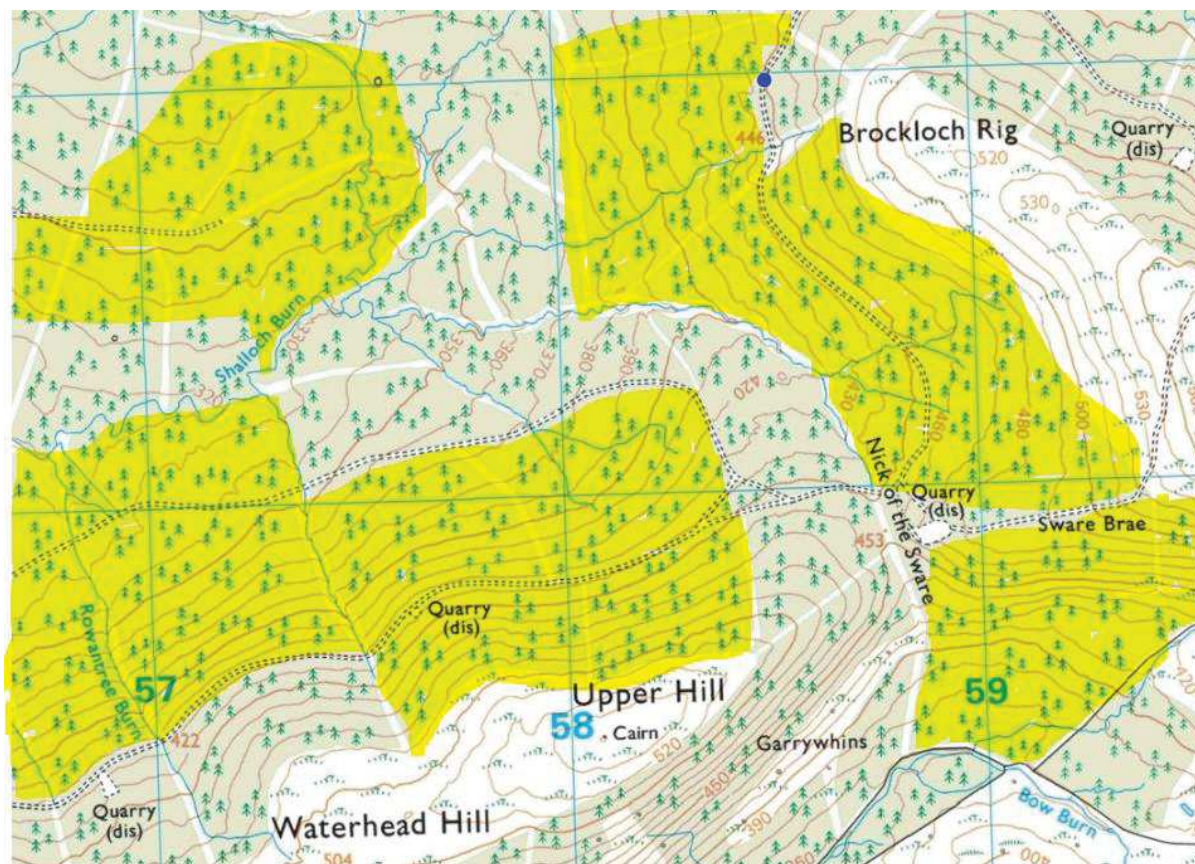
Photos of proposed locations, looking south and west from access track

Observations:

- Areas listed for UDM have been cleared, however some areas exhibiting regrowth
- Channels flowing north from Waterhead Hill are often small, with plunge pools and falls
- Channel bedload is mainly fine sediments and is discoloured by the peat
- Debris often in the channel reducing flow rate

PHOTOGRAPH LOCATION

Grid Reference –NS 58509 01970 (Blue marker denotes location. Yellow highlights mark observed locations and confirm the extent of deforestation)



SURVEY PHOTOGRAPHS (5B)



SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	5C

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

5C – Land south of Brockloch Rig (Windy Standard)

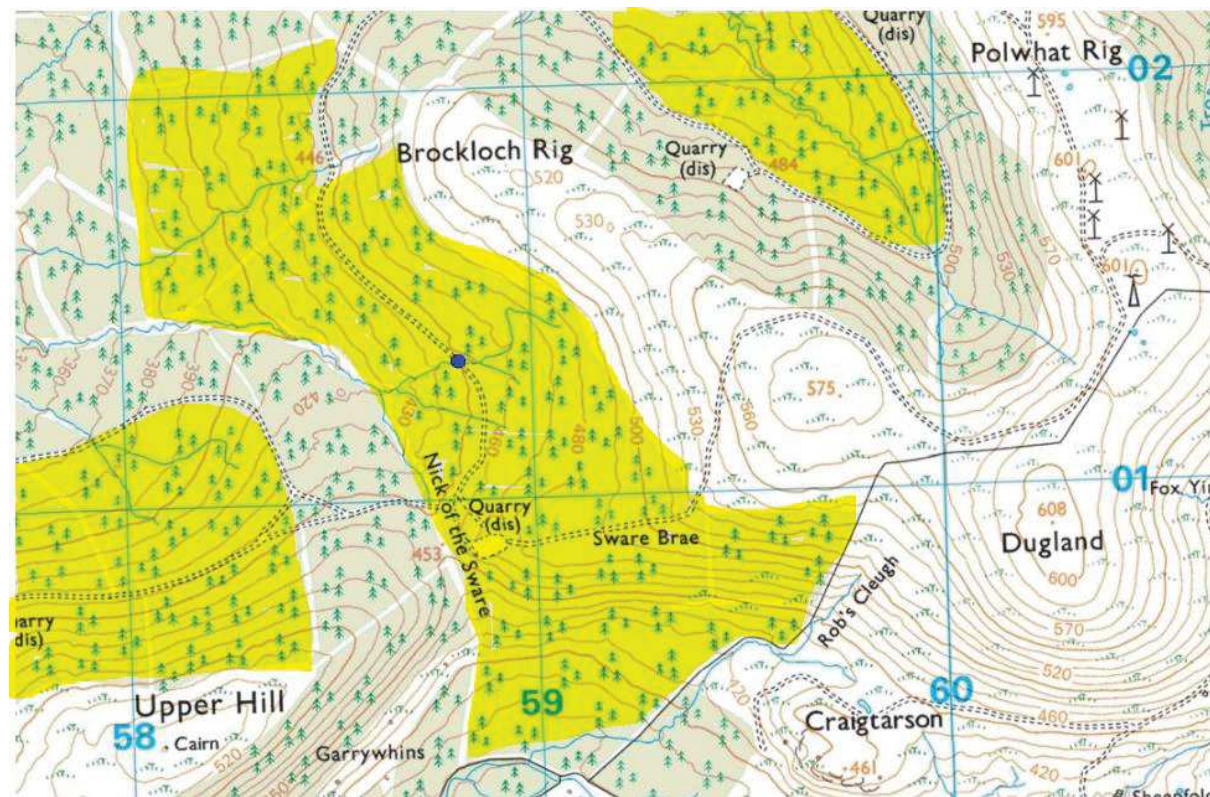
Photos of proposed locations, looking north from access track and inspection of channel

Observations:

- Areas listed for upland drainage management have been cleared, however some areas exhibiting regrowth
- Channels flowing west was small, with plunge pools and falls
- Channel bedload is mainly fine sediments and is discoloured by the peat
- Debris often in the channel reducing flow rate
- Channel was close to being dry so could be ephemeral in summer

PHOTOGRAPH LOCATION

Grid Reference –NS 58858 01278 (Blue marker denotes location. Yellow highlights mark observed locations and confirm the extent of deforestation)



SURVEY PHOTOGRAPHS (5C)





SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	5D

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

5D – Observations of Cairnsmore of Carsphairn (Windy Standard)

Photos of proposed locations, looking south and east from access track

Observations:

- Mountainside comprises of steep heather / peatland terrain
- Drainage channels likely to be incised into peat but are not well defined, with re-entrant features around burns being very minor
- Soil appears shallow with smoothed bedrock visible as outcrops nearby
- In channel techniques may be effective however planting tree may be difficult due to shallow soil and exposure to wind

Additional Notes – From observations made from the photo location, the Site access will be very difficult / impossible for vehicles

PHOTOGRAPH LOCATION

Grid Reference –NS 58946 00884 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (5D)



SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	5E

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

5E – Goat Burn

Photos of immediate catchment and channel morphology

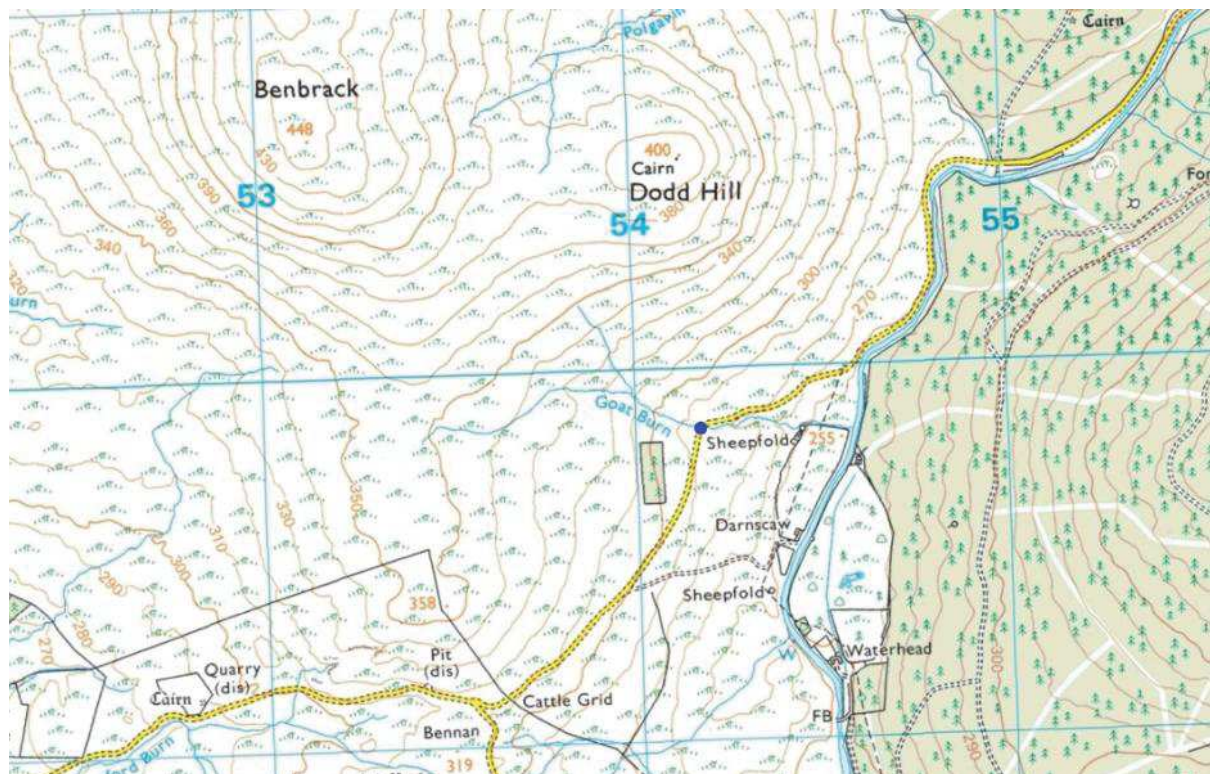
Observations:

- Channel slope ~10-15 degrees with moderate flow speed
- Minor channel which is incised into peat and soil with plunge pools and falls
- Channel is ~0.1-0.3m wide with depth depending on plunge pool but no more than 0.3m
- Bedload is fine gravel, sand and silt but has a coating of moss
- Banks comprise of grasses and moss
- Extensive artificial drainage ditches accords the hill sides feeding into the channel

Additional Note – bankside vehicular access is good at this location

PHOTOGRAPH LOCATION

Grid Reference –NX 54182 99830 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (5E)





SURVEY DETAILS

Date:	2017-04-05	Site:	Galloway Glens
Hydrologist:	Sam Wainwright	Location ID:	5F

WEATHER DETAILS

During Site Visit:	Cold, 8 degrees, overcast
Recent Weather:	Overcast with light rain

COMMENTS

5F – View of Lamford Hill

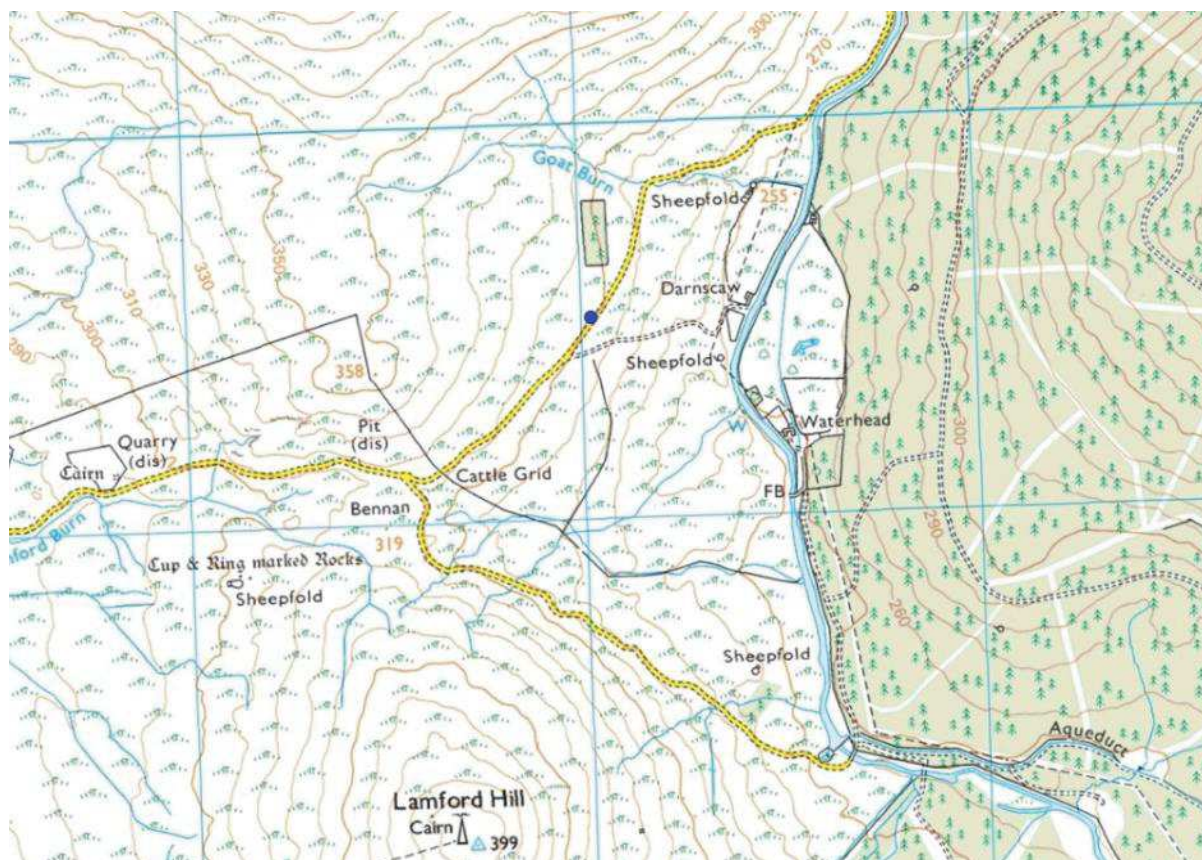
Photos of Lamford Hill looking east, south east

Observations:

- Grazed grassland with tussocks
- Several small natural drainage channels as well as addition artificial drainage channels running predominantly vertically down the hillside

PHOTOGRAPH LOCATION

Grid Reference –NX 54016 99473 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (5F)



3. New Galloway

SURVEY DETAILS

Date:	2017-06-14	Site:	Galloway Glens
Hydrologist:	Scott Bennet	Location ID:	NG1

WEATHER DETAILS

During Site Visit:	Mild, 12 degrees
Recent Weather:	Overcast with sunny intervals

COMMENTS

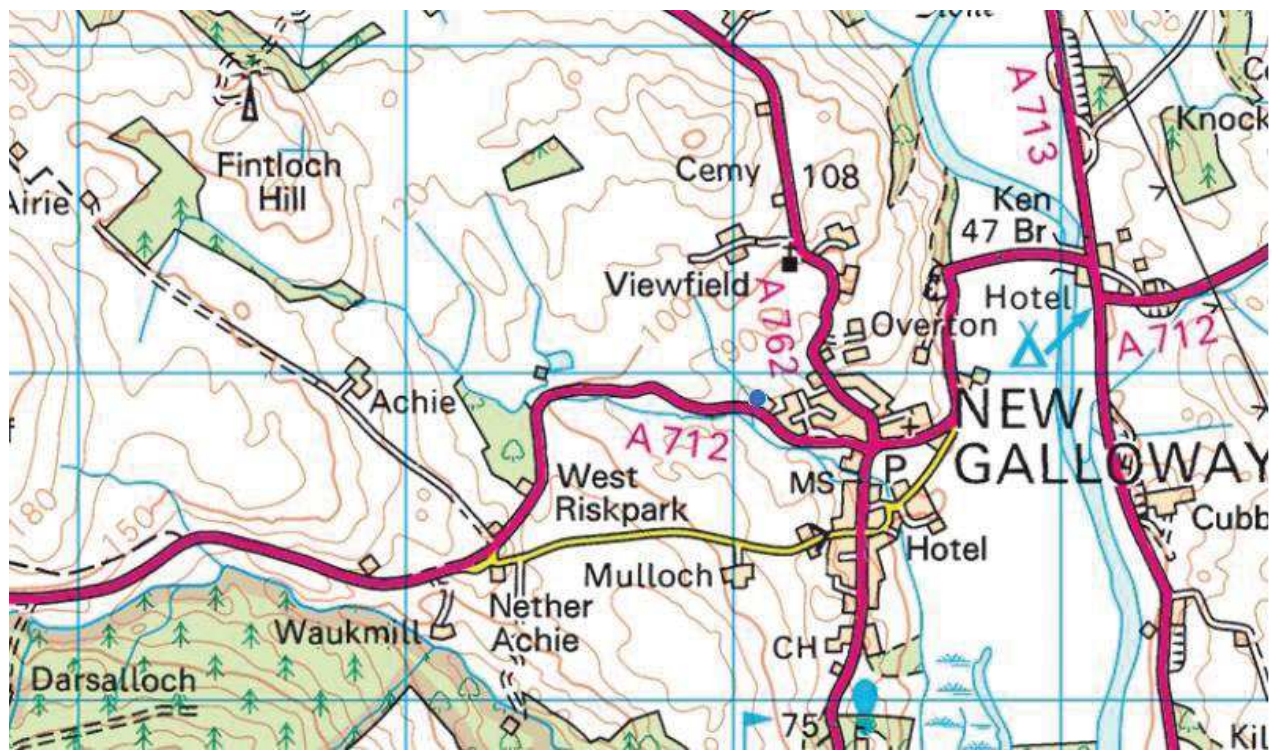
NG1 – View north of unnamed tributary of Mill Burn

Observations:

- Heavily grazed grassland with water logged and heavily vegetated riparian corridor
- Sparse presence of trees along the riparian corridor

PHOTOGRAPH LOCATION

Grid Reference –NX 63062 77925 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (NG1)



SURVEY DETAILS

Date:	2017-06-14	Site:	Galloway Glens
Hydrologist:	Scott Bennet	Location ID:	NG2

WEATHER DETAILS

During Site Visit:	Mild, 12 degrees
Recent Weather:	Overcast with sunny intervals

COMMENTS

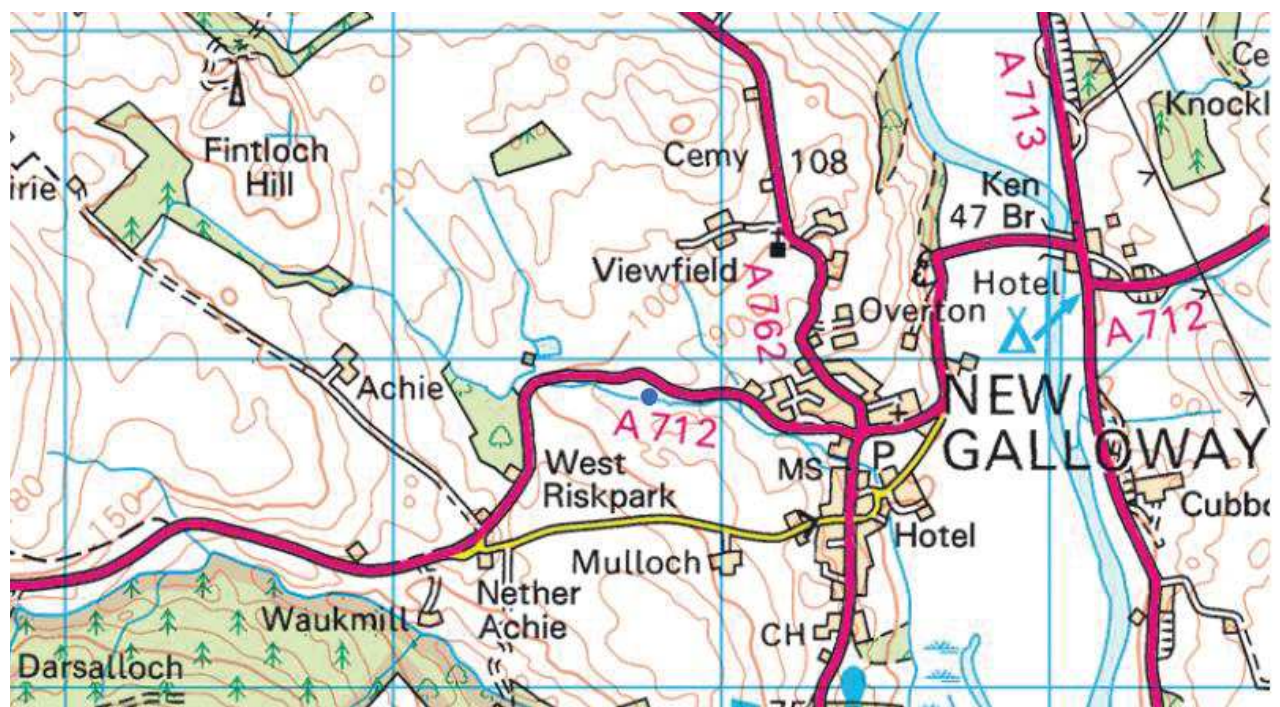
NG2 – view upstream and downstream of Mill Burn

Observations:

- Heavily grazed grassland with water logged and heavily vegetated riparian corridor
- Evidence of livestock of watercourses, with minor areas of exposed soils
- Riparian corridor dominated by grasses, interspersed with sparse denser vegetation
- Coarse bed material

PHOTOGRAPH LOCATION

Grid Reference –NX 62783 77886 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (NG2)





SURVEY DETAILS

Date:	2017-06-14	Site:	Galloway Glens
Hydrologist:	Scott Bennet	Location ID:	NG3

WEATHER DETAILS

During Site Visit:	Mild, 12 degrees
Recent Weather:	Overcast with sunny intervals

COMMENTS

NG3 – View north east

Observations:

- Heavily grazed grassland with extensive network of existing field boundaries. Potentially suitable for the plantation of hedgerows along these boundaries

PHOTOGRAPH LOCATION

Grid Reference –NX 61942 77800 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (NG3)





SURVEY DETAILS

Date:	2017-06-14	Site:	Galloway Glens
Hydrologist:	Scott Bennet	Location ID:	NG4

WEATHER DETAILS

During Site Visit:	Mild, 12 degrees
Recent Weather:	Overcast with sunny intervals

COMMENTS

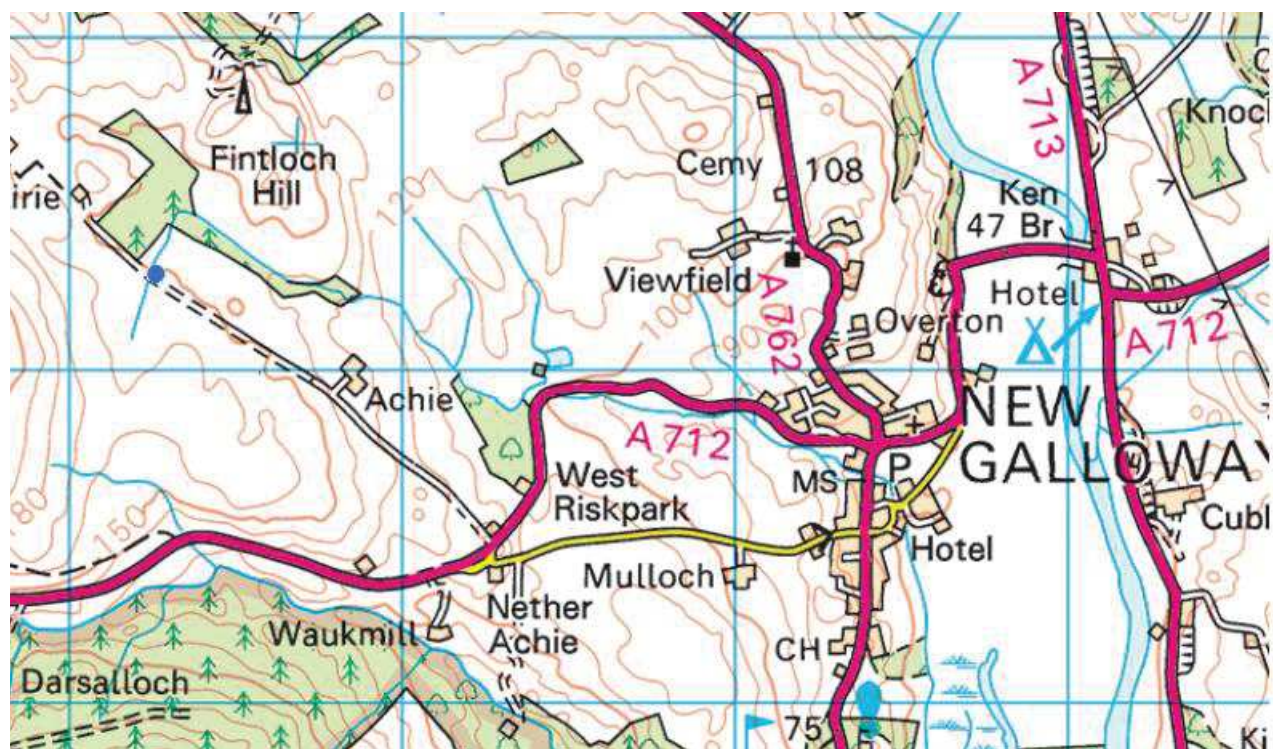
NG4 – View north, headwaters of the Mill Burn

Observations:

- Heavily grazed catchment
- Riparian corridor dominated by grasses, interspersed with sparse denser vegetation
- Good vehicular access

PHOTOGRAPH LOCATION

Grid Reference –NX 61297 78329 (Blue marker denotes location)



SURVEY PHOTOGRAPHS (NG4)



What we do

Natural Power is a leading independent renewable energy consultancy and products provider. The company offers proactive and integrated consultancy, management and due diligence services, backed by an innovative product range, across the onshore wind, offshore wind, wave, tidal, renewable heat, solar pv and hydro sectors, whilst maintaining a strong outlook on other new and emerging renewable energy sectors.

Established in the mid 1990s, Natural Power has been at the heart of many groundbreaking projects, products and portfolios for more than two decades, assisting project developers, investors, manufacturers, research houses and other consulting companies. With its iconic Scottish headquarters, The Green House, Natural Power has expanded internationally and now employs more than 330 renewable energy experts.

Creating a better environment

Our global expertise

Natural Power delivers services and operates assets globally for our clients, with eleven offices across Europe and North America and agencies active in South America and AsiaPac.

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