Appendix A: Project approach

A.1 Introduction

This study is based on the approach used in the Natural England Character Area Climate Change Project [21]. In common with the forthcoming Character Area studies, the Forest of Bowland AONB climate change adaptation plan is underpinned by three main concepts:

- Sustainable adaptation;
- Using a vulnerability approach to assess the potential impacts of climate change; and
- Using landscape as an integrating framework for adaptation.

This appendix defines these concepts and describes how they have been used to inform the methodology.

A.2 Sustainable adaptation

Adaptation needs to be sustainable in order that action taken now does not have unintended negative consequences. Four principles for sustainable adaptation have been proposed[22]:

- Adaptation should aim to maintain or enhance the environmental, social and economic benefits provided by a system, while accepting and accommodating inevitable changes to it;
- Adaptation should not solve one problem while creating or worsening others. Actions which have multiple benefits should be prioritised and actions which create negative effects for other people, places and sectors should be avoided;
- Adaptation should seek to increase resilience to a wide range of future risks and address all aspects of vulnerability, rather than focusing solely on specific projected climate impacts; and
- Approaches to adaptation must be flexible and not limit future action.

From these principles, a simple framework for considering adaptation options has been developed. This framework follows a structure of 'value, vulnerability, response'. The starting point is to consider the benefits a system provides, in order to establish objectives for adaptation against which both the consequences of climate change and the sustainability of possible adaptation actions can be evaluated. Subsequent steps in framework involve assessing all aspects of vulnerability of the things we value, and then identifying appropriate adaptation responses that will address specific aspects of vulnerability while having maximum benefits and minimum negative effects.

An important aspect of sustainable adaptation is to identify action that would maintain or enhance the multiple benefits an area provides to society by reducing vulnerability to a range of possible consequences of climate change (principle 3 above). Therefore, a specific climate change scenario (e.g. 2080s, high emissions) has not be chosen to assess the vulnerability of the natural environment or identify adaptation responses in this project. The project aims to develop adaptation responses which are valid for a broad range of climate changes, using the headline messages from the United Kingdom Climate Projections 2009 (UKCP09) (see Section 2.3).

In the face of uncertainty about the magnitude and timing of climatic changes and the cascade of possible consequences for natural systems, it was felt that this approach is more appropriate than focusing solely on trying to identify and respond to detailed projections of climate impacts.

[21] *Natural England, 2009 a, b, c, d and forthcoming Natural England publications*

[22] *Macgregor and Cowan, 2010*

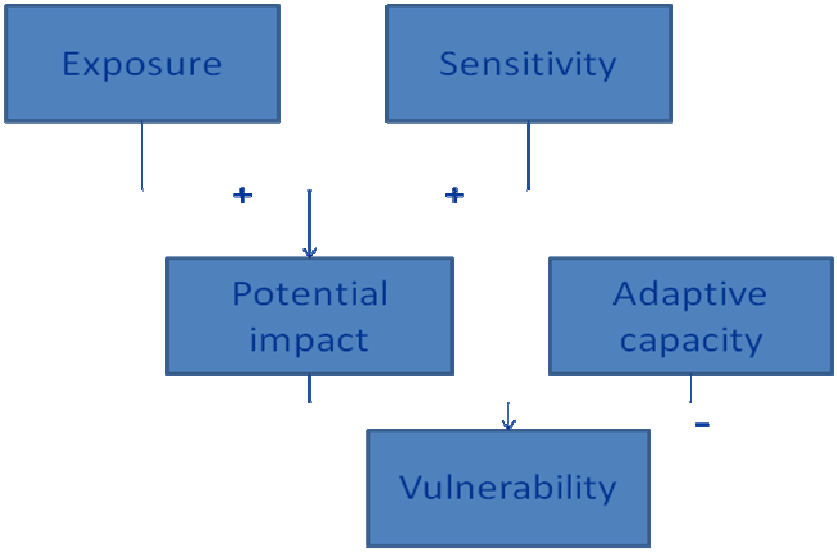
A.3 Vulnerability assessment

Vulnerability has been defined by the Intergovernmental Panel on Climate Change (IPCC) as a function of a system's exposure and sensitivity to climate impacts and its capacity to adapt[23], where:

- Sensitivity refers to the degree to which a system is affected by weather or climate related stimuli[24];
- Exposure refers to the extent to which the system is subject to the weather or climate variable in question; and
- Adaptive capacity refers to the ability of a system to adjust to climate change, to moderate potential damage or to take advantage of opportunities[25].

Figure A.1 summarises the three-element vulnerability framework as described by the IPCC.

Figure A.1 - Components on vulnerability according to the IPCC



The IPCC vulnerability framework distinguishes between 'natural' and 'human-managed' adaptive capacity, and further studies[26] have explored in detail the factors that influence vulnerability in complex natural systems.

Exposure is determined by two factors. The first of these is the general change in climate variables that occurs in the area of interest. Information on change in climate variables can be found in the UKCP09 projections[27]. The UKCP09 projections provide probabilistic projections of climate change, assimilated from an ensemble of models and model runs for three emissions scenarios (Low, Medium and High). The projections are presented for 25 x 25 km grid squares across the UK and for seven over-lapping 30-year 'timeslices' (30 year averages of climate variables), moving forward in decadal steps (2010-2039, 2020-2049, until 2070-2099).

Headline messages (for the UK) from UKCP09 can be summarised as:

- All areas of the UK get warmer and the warming is greater in summer than in winter;
- There is little change in the amount of precipitation that falls annually but it is likely that more of it will fall in winter with drier summers for much of the UK; and
- Sea levels rise and the relative rise is greater in the south of the UK than the north.

Projections of climate change for the north west of England can be found in Box 1 (in Chapter 3).

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[23] *IPCC, 2007*

[24] *Willows and Connell, 2003*

[25] *Ibid*

[26] *Williams et al., 2008*

[27] *Murphy et al., 2009*

Second, the exposure of a particular feature (e.g. a plant or an animal, or an archaeological feature) may be moderated by the physical structure of the environment in the immediate vicinity. For example, even though an overall area might experience a certain average temperature rise, sites that are naturally cool and shaded (e.g. sheltered wooded valleys) are likely to experience a lower temperature rise than nearby sites in direct sun, such as open hilltops.

Sensitivity to a climatic change is determined *by intrinsic traits* of a feature, such as a species' tolerance to changes in temperature or water availability or the type of material used to build a historic property and the extent to which it is affected by flooding. Sensitivity in a particular location is also likely to be exacerbated by the presence of non-climate pressures. For example, areas of blanket bog that are already water-stressed as a result of existing drainage are likely to be more sensitive to additional water shortage in drier summers than are areas in good condition with sufficient water resources. Historic features in a poor state of repair might be more sensitive to damage from heavy rainfall than features that have been well conserved.

Capacity to adapt is determined by three sets of factors:

For living things, it is the *intrinsic traits* of a species that enable it to adjust to changing conditions. This includes the ability to modify behaviour to use different microhabitats or to be active at different times of the day; phenotypic plasticity, such as the ability of some plants to develop leaves of a different shape to cope with hotter drier conditions; the ability of an animal, or the seeds of a plant, to disperse to other, more suitable areas; changes in phenology, that is timing of seasonal events such as egg hatching, migration and leafing; and capacity to adapt (in an evolutionary sense) in situ to be more adapted to the new conditions, which will be constrained by the existing level of genetic diversity in a population and the species' generation time.

The *local environment*, which can either support or hamper a species' intrinsic ability to adapt. For example, a species might have the ability to modify its behaviour to use different microhabitat in its current range, or to disperse to new habitat in a different area, but will be able to successfully adapt if suitable habitat is available and accessible.

For both living and non-living features, the ability of humans to manage the system *('adaptive management capacity'*[28]*)*. Factors such as the existence of management plans or policies which consider climate change, resources, measurement and monitoring of the impacts of climate change, availability of land for people to allow translocation or migration of living and non-living features, and the existence of partnerships to manage features can all contribute to adaptive management capacity. Adaptive management capacity may have strong links with the local environment factors noted above.

A.3.1 Dealing with uncertainty in vulnerability assessment

There are multiple sources of uncertainty in the vulnerability assessment that make it difficult to make an objective assessment of the vulnerability of features of the natural environment to the impacts of climate change. There are a range of projections of climate change due to incomplete understanding of Earth system processes and a range of possible scenarios of future greenhouse gas emissions[29]. Another source of uncertainty is added when translating the projections into potential impacts on the natural environment: our understanding of how the complex interactions in the natural environment will respond to climate change is limited.

While acknowledging these various sources of uncertainty, we understand enough about possible climate change and its potential effects on the natural environment to consider a range of plausible future changes. The aim of the vulnerability assessment in this project was to highlight the relative vulnerability of features in the AONB to the impacts of climate change, based on the best knowledge available at present. Sources of information included expert judgement of national specialists from Natural England and other organisations, local experts and representatives of conservation organisations and Local Planning Authorities (LPAs) and published literature. By setting out each feature in terms of its exposure and sensitivity to climate change and its capacity to adapt, the justification for the assessment is made as transparent as possible (see Chapter 3 for a detailed discussion of the methodology used in the project).

[28] *Williams et al., 2008*

[29] *Jenkins et al., 2009*

A.4 Landscape as an integrating concept

The third central concept is the idea of landscape as an integrating framework for adaptation (and for conservation in general). Landscape is considered in terms of a range of physical features that combine and interact to produce important services and benefits. Three broad categories of benefits are considered: landscape character, ecosystem services and biodiversity.

1. Landscape character encompasses physical and cultural patterns and appearance and refers to the aspects of a landscape which make it distinctive. The concept of landscape character does not imply any value judgement i.e. it does not make a distinction between landscapes that are better or worse but considers the distinct, recognisable and consistent pattern of elements that make one landscape different from another. This might include physical features such as hedgerows or buildings but also physical patterns at different spatial scales. These elements come together to influence how people perceive landscapes and contribute to a sense of place.

2. Ecosystem services are the range of goods and services provided by natural ecosystems from which humans derive benefit[30]. This study considers the full range of ecosystem services. The Millennium Ecosystem Assessment[31] identified four types of ecosystem services:

- Provisioning services such as food and forestry, energy and fresh water;
- Regulating services such as climate regulation and water purification;
- Supporting services such as soil formation and pollination; and
- Cultural services such as recreation, inspiration and sense of place.

3. Biodiversity contributes to and underpins much of landscape character and ecosystem services but it also has intrinsic value. Biodiversity is generally taken to refer to habitats and species and the interactions which exist between them. However, because of the broad scale at which the assessment of vulnerability is being carried out, this study largely focuses on habitats.

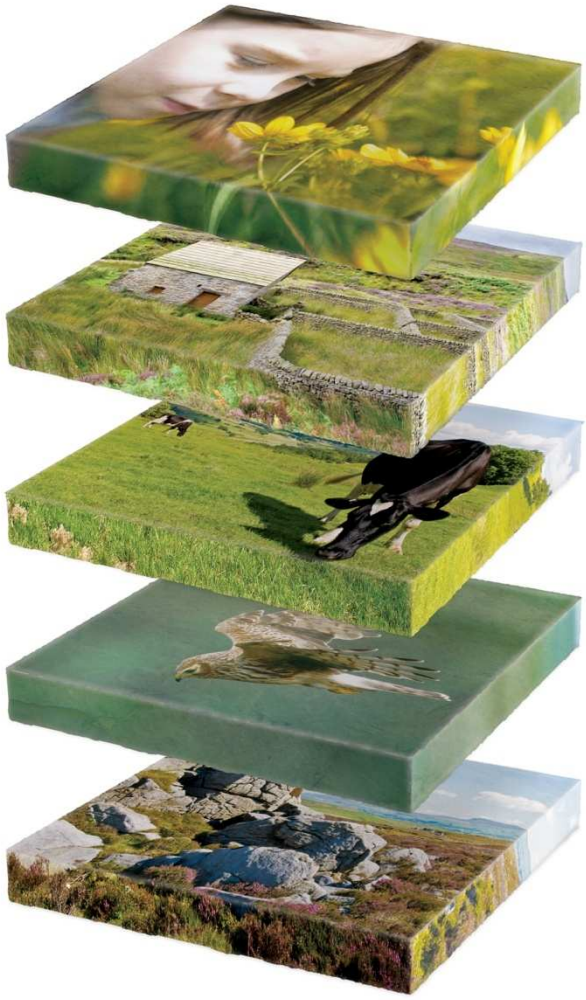
Landscape character, ecosystem services and biodiversity are the result of a combination of elements such as habitats, geology, soil types and land use and the interactions between them. Figure A.2 illustrates how these different components combine to form landscape in the Forest of Bowland AONB. The elements which make up the landscape character of an area, or which contribute to the ecosystem services it provides are made up of the component parts of that landscape, referred to as 'assets' in this study. A simple example of this might be trees and hedgerows which combine to give a landscape a well wooded character and also deliver services such as carbon sequestration or soil conservation.

This study brings together these three concepts (sustainable adaptation, vulnerability assessment, landscape as an integrating framework) to develop a methodology for an integrated landscape and ecosystem service approach to adaptation.

[30] *POST, 2007*

[31] *Millennium Ecosystem Assessment, 2005*

Figure A.2 - Components of the landscape in the Forest of Bowland AONB ©Countryscape



Appendix B:

Further detail on execution of project methodology

B.1 Steps 1 and 2

This section summarises the results of Steps 1 and 2 of the method. The landscape characteristics, ecosystem services and biodiversity of the AONB and the assets which contribute to them are described below and full lists of contributing assets can be found in Tables B.1 and B.2.

B.1.1 Landscape character

Landscape character types have been identified from the Forest of Bowland AONB Landscape Character Assessment. For more detail see the map at Figure1.1

A. Moorland plateaux

The moorland plateaux character type is found on the very tops of the Bowland Fells at elevations of 400-560m. These areas are characterised by a series of wide, flat topped or gently rolling ridges covered by upland habitats such as heather moorland, dwarf-shrub heath and purple moor grass. Peat soils support blanket bog (see Figure B.1) and preserve buried archaeology. Man-made structures are features in these areas, including grouse butts, dry stone walls, tracks and stone cairns.

Figure B.1 - Blanket bog in the moorland plateaux landscape type

©Countryside Agency/Charlie Hedley 03-4372

B. Unenclosed moorland hills

The unenclosed moorland hills character type is found at the edge of the moorland plateaux and generally occurs at lower elevations. The hills have distinctive rounded profiles and are covered with heather moorland, acid grassland and where there are peat soils, blanket bog. Fast flowing streams support clough woodland and riparian bird species. These

areas are characterised by a lack of enclosure features, giving them a sense of tranquillity. There is relatively little evidence of human activity although there are a few isolated farm buildings and historic quarries.

C. Enclosed moorland hills

The enclosed moorland hills character type encircles the moorland plateaux at lower elevations. These areas are characterised by distinct hill profiles, steep escarpments and cloughs. There is a mosaic of upland habitats including heather moorland, acid grassland and blanket bog interspersed with conifer woodland and bracken. There is more evidence of human history than in the unenclosed moorland hills: historic field patterns; gritstone walls (see Figure B.2); sheep folds; and tracks are features in the landscape.

Figure B.2 - Dry stone walls in the enclosed moorland hills landscape character type ©Graham Cooper

D. Moorland fringe

The moorland fringe character type is a transitional, rolling and enclosed landscape which skirts the edges of the moorland hills. This character type links upland and lowland areas and as such is characterised by a mix of moorland and grassland habitats. There is significant evidence of human history and agriculture including dry stone walls, vaccaries, sheepfolds and quarries. In-bye pasture is still used for sheep grazing.

E. Undulating lowland farmland

This character type covers much of the lower parts of the AONB. These areas are predominantly farmed and are characterised by irregular fields, boundary features such as dry stone walls and hedgerows and historic field patterns. Ancient woodland and wood pasture are found in cloughs. Man-made features such as settlements and roads are features in the landscape of these areas.

F. Undulating lowland farmland with wooded brooks

This character type is found in lowland areas, generally below 150m. A sub set of the undulating lowland farmland type, it is characterised by a patchwork of pastoral fields, hay meadows and medieval enclosure features. Fields are incised by wooded brooks which support a range of woodland types, including broadleaved woodland, alder and ash clough woodland and lowland oak woods. Wet areas also support small areas of fen and marshy grassland. Small settlements are linked by a network of lanes.

G. Undulating lowland farmland with parkland

This type, a further subset of undulating lowland farmland, generally occurs below 150m and comprises pasture, interspersed with country houses and associated designed landscapes e.g. Cow Ark, Browsholme Hall, Stonyhurst

College, Winckley Hall, Abbeystead and Knowlmere Manor. Many estates include parkland which is characterised by calcareous grassland with clumps of woodland and veteran trees. Flushes support small areas of fen and marshy grassland and there are some examples of herb rich grassland.

H. Undulating lowland farmland with settlement and industry

This landscape character type, also a subset of undulating lowland farmland, is characterised by a patchwork of pastoral fields punctuated by main transport corridors and relatively large urban areas. Modern man-made features are prominent in the landscape, including post and wire fences, working quarries and other industrial buildings. There is also evidence of a long history of settlement in these areas including historic quarries, castles and dry stone walls.

I. Wooded rural valleys

Deeply incised wooded valleys link upland and lowland areas, creating a pattern of linear landscapes which radiate out from the central fells. Ancient ash, alder and willow woodlands are found on the valley sides and herb rich pastures are found in valley bottoms (see Figure B.3). There are also some areas of managed woodland planting and coppicing. Features created by the action of water are prominent in the landscape including waterfalls, gorges and stepped terraces. Historic man-made water features such as mill ponds, races and sluices and also characteristic.

J. Valley floodplains

The AONB is dissected by a number of substantial rivers including the river Ribble to the south and the Lune to the north. These are wide, slow, rivers which meander across open, broad and flat floodplains, creating features such as oxbow lakes and terraces. These areas are characterised by open water and wetland habitats including lowland bogs, floodplain grassland and shingle margins which are important for breeding birds. There is considerable evidence of historic settlement in these areas and floodplain soils preserve buried archaeology.

K. Drumlin fields

These areas are characterised by distinctive rounded hills, a product of glacial deposition, usually 100-200m high, which occur in 'fields' or clusters, usually aligned in one direction. Ancient woodland is found on the steep scarp slope and wetland habitats such as remnant mires and swap and tall herb vegetation are found where rivers dissect the hills. Farmsteads are found on top of the hills and there are some historic field patterns.

Figure B.3 - Wooded brooks and wet woodland ©Graham Cooper

L. Rolling upland farmland

These areas are predominantly pastoral and structures such as sheep folds and farmsteads are features in the landscape. Herb rich pastures and hay meadows are found on the lower slopes and higher up the hills are covered with moorland grasses and beech woodland.

M. Forestry and reservoir

Man made features dominate the character and feel of these areas. Coniferous and broadleaved woodlands have been planted for commercial forestry but support a number of bird species. Reservoir draw down zones provide an important habitat for specialised flora and breeding and over-wintering wildfowl. Modern and historic man-made features associated with the reservoirs are features in the landscape, including a disused railway and the church at Stocks Reservoir.

N. Farmed ridges

The farmed ridges character type is found on relatively low land, typically ridges have elevations of 140-230m and distinctive rounded profiles. These areas are intensively farmed and pasture is used to graze beef and dairy cattle. From the ridges there are long, open views across the surrounding lowlands.

Table B.1- Identification of assets contributing to landscape character in the Forest of Bowland AONB

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
A. Moorland plateaux	Lie on the very tops of the Bowland Fells at elevations of 400-560m. A series of wide, flat topped or gently rolling ridges.	Heather moorland and dwarf-shrub heath Blanket bog Golden plover, curlew, red grouse, hen harrier, peregrine, merlin Largest breeding colony of lesser black backed gulls in Europe on Mallowdale and Tarnbrook fells- also Langden Head Fast flowing upland streams Acid grassland Purple moor grass and/or cottongrass	Bare peat Underlying gritstone – terraces and escarpments Boulders and gritstone crags Cloughs Podsols and gleyed clay soils	Flint and chert implements Buried archaeology in the peat		Grouse butts Cairns and other stone towers Shooting tracks and sheep tracks Footpaths Sheep folds Boundaries (fencelines or dry stone walls)

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
B. Unenclosed moorland hills	Cloak the edges of the Moorland Plateaux and generally occur at lower elevations. The hills have distinctive rounded profiles, and they are characterised by a lack of dry stone walls – giving them a sense of remoteness and tranquillity, with little evidence of human activity.	Acid grassland Heather moorland Fast flowing upland streams with riparian birds such as grey wagtail, dipper and common sandpiper Blanket bog Bracken Meadow pipits, skylarks and red grouse, hen harrier, curlew, peregrine, merlin, ring ouzel and golden plover Largest breeding colony of lesser black backed gulls in Europe on Mallowdale and Tarnbrook fells Upland oak and mixed ash woodland (in cloughs) Conifer woodlands Wet flushes and springs	Gritstone and softer shales – terraces and escarpments Gritstone outcrops Glacial erratics Cloughs e.g. Little Mearly Clough SSSI Shallow podzolic soils Peat soils (areas above 400m)	Vaccaries Historic gritstone quarries at Clougha, Wolf Fell and Saddle Fell; and peat cutting on Parlick Fell, Wolf Fell, Pendle Hill and Goodber Common. Abandoned farmsteads and field barns		A few shooting huts, tracks and towers Grouse butts Isolated gritstone buildings Unfenced roads

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
C. Enclosed moorland hills	Encircle the Moorland Plateaux at lower elevations. Characterised by distinct hill profiles. More evidence of human history.	Fast flowing upland streams Heather moorland Acid grassland Oak woodland Bracken Blanket bog Conifer woodland Wet flushes and springs Merlin, hen harrier, curlew, peregrine and golden plover	Cloughs Grit crags and glacial erratics Steep escarpments Millstone Grit and shales Peat soils (areas above 400m) Boulder clay Rock outcrops e.g. Bowland Knotts RIGS	Gritstone walls, with throughstones Small, isolated stone hamlets and farmsteads Historic field patterns	Quarries	Large fields Sheepfolds Shooting tracks and butts Unfenced roads

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
D. Moorland fringe	Transitional rolling enclosed landscape skirts the edges of the Moorland Hills, usually at an elevation of more than 200m. Links the upland to the lowland landscape. More evidence of human history.	Herb rich grassland – Myttons Meadows SSSI Heather moorland Damp pastures – wading birds. Curlew and lapwing and snipe Hares Unimproved grassland Manchester Treble-bar and a rare spider, *Clubiona norvegica*, at Caton Moor. Roadside verges	Gritstone Limestone in the Hodder Valley Bowland series of Millstone grits, sandstones and shales-Little Mearley Clough SSSI and Light Clough SSSI	Dry stone walls Stone out-barns Sheepfolds Tramways and tracks Quarries and mines Parkland Laithe houses Vaccaries Packhorse ways Buried archaeology	In-bye pasture for sheep Reservoirs	Quaker Meeting Houses and churches

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
E. Undulating lowland farmland	Covers much of the lower parts of the AONB. Predominantly farmland	Hedgerows Wading birds, hares and roe deer Roadside verges Ancient woodland in cloughs, upland oak woods, wood pasture Streams	Boulder clay Limestone, grit, shale and sandstone Cloughs Base rich soils in valley floors	Isolated farmhouses with veteran trees Dry stone walls where boulder clay is absent Roman kilns at Quernmore Ridge and furrow field patterns Farm kilns	Quarries Managed planting and coppicing	Stone villages - Whitechapel and Quernmore Churches Intensive farming Irregular fields Major transport corridors Small scale industry e.g. cheese making

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
F. Undulating lowland farmland with wooded brooks	Lowland landscape generally below 150m. Patchwork of pastoral fields incised by wooded brooks and river gorges, which provide a sense of enclosure.	Broadleaved woodland – wild garlic and bluebells Streams Herb rich verges Clough woodlands – alder and ash. Roe deer and badgers Hedgerows Lowland oakwoods and upland oak woods on the upper valley sides Remnant species-rich grassland Flushes, fens and marshy grassland Hay meadow - New Ing Meadow SSSI Roadside verges	Cloughs Limestone (Cross Hill Quarry RIGS), grit, shale and sandstone Deep deposits of glacial drift and fluvial glacial deposits e.g. Bashall Brook RIGS (exposure of fluvial and fluvial glacial deposits) and Grindleton Dyke RIGS Base rich soils in valley floors	Historic water powered industry - mills at Calder Vale, Caton and Sabden. Medieval enclosure – hedgerows and dry stone walls Industrial villages e.g. Calder Vale		Network of minor lanes and humpback bridges Small, irregular fields Small linear villages Gritstone terraced cottages

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
G. Undulating lowland farmland with parkland	Generally occurs below 150m and comprises pasture, interspersed with country houses and associated designed landscapes, particularly parkland	Pasture Upland calcareous grassland – Bowland Knotts Rock outcrops e.g. Bowland Knotts BHS/RIGS and Clitheroe Knoll Reefs SSSI Parkland - trees, specimen trees, veteran trees, clumps of woodland, beech hedgerows Flushes, fens, marshy grassland and small streams Herb rich grassland – Bell Sykes Meadow SSSI Roadside verges	Limestone, grit, shale and sandstone Rock outcrops e.g. Bowland Knotts RIGS Deep drift deposits Clitheroe Reef Knolls SSSI - classic site for the study of knoll-reefs in the Asbian Carboniferous Limestone of England. Disused quarry e.g. Cutters and Dale House Quarries RIGS near Chipping Stream sections e.g. Phynis Beck RIGS	Country houses and designed landscapes – parkland e.g. Cow Ark, Browsholme Hall, Stonyhurst College and Winckley Hall Ornamental planting Metal railings, follies, ha has Estate villages e.g. Downham and Slaidburn Dry stone walls		

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
H. Undulating lowland farmland with settlement and industry	Patchwork of pastoral fields punctuated by main transport corridors and relatively large urban areas. Generally viewed against either the backdrop of Moorland Hills or Pendle Hill.	Hedgerows Streams	Soft glacial tills Isolated hills and reef-knolls e.g. Worston Coplow, Salthill and Bellmanpark quarries SSSIs Disused quarries e.g. Withgill Quarry RIGS	Victorian buildings Norman castle at Clitheroe Dry stone walls Standen Hall	Limestone quarries and cement works at Clitheroe River Ribble	Post and wire fences Rows of terraced houses Towns of Clitheroe and Whalley Major roads Railway line Industry including tarmac works, cement works and industrial estates

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
I. Wooded rural valleys	Deeply incised wooded valleys link upland and lowland Bowland, creating a strong pattern of linear landscapes, which radiate out from the central fells.	Ancient woodland - ash or alder/willow fringing streams, upland oak woodland along valley sides - pied flycatcher , wood warbler and redstart Herb rich pastures and meadows in valley bottoms e.g. Far Holme Meadow, Tarnbrook Meadows and Clear Beck Meadow SSSIs. Rivers and ponds Artle Dale -bryophyte (moss and liverwort) communities. Riparian birds such as grey wagtail, dipper and common sandpiper	Gritstone, shales and silt Waterfalls and gorges Landslips – hummocky local topography Stepped terraces e.g. Hodder River Section SSSI for exposures of Lower Carboniferous rocks.	Mill lodges and historic mill sites - including mill ponds, races, sluices and weirs. Packhorse bridges Deserted church at Littledale Stone field barns	Managed planting and coppicing	Settlements above the tree line Fords

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
J. Valley floodplains	Ribble to the south and the Lune to the north are wide, slow, rivers, meandering across open, broad and flat floodplains.	Standing water Rivers Lowland bogs and domed mosses Hay meadows Floodplain grassland Hedgerows Mature floodplain trees Shingle and shallow wet margins important for breeding birds Eroding banks nesting habitat for kingfisher and sand martin Lune valley – upland sessile oak woodland	Glacial tills River gravels and alluvium deposits Accumulations of peat in hollows Eroding banks Oxbow lakes Large meandering rivers with terraces at floodplain edges	Historic flood defences Archaeological sites Norman motte and bailey castles e.g. the Castle Stead near Hornby, Sawley Abbey Routeways and stone bridges Field margins - hedgerows	Grazing land – cattle and sheep	Post and wire fencing Settlements Cheese making industry

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
K. Drumlin Fields	Distinctive rounded hills, usually 100-200m high, which occur in 'fields' or clusters, and are usually aligned in one direction. Formed from glacial deposits, moulded into steep sided, rounded topped hills by the ice. A landscape with smooth hills, winding rivers and farmsteads atop the hills.	Ancient woodland on the steep scarp slopes above the Lune and its tributaries Hedgerows Remnant mires, raised bogs e.g. Austwick and Lawkland Mosses SSSI Pockets of species rich grassland Swamp and tall herb vegetation Unimproved grassland e.g. Robert Hall Moor SSSI	Narrow streams Field of rolling drumlins Solid rock outcrops	Stone walls Historic field patterns, some ridge and furrow Roman roads Isolated limestone field barns		Major roads around the area Settlements on the sheltered lower slopes
L. Rolling upland farmland	Predominantly pastoral landscape. Gentle landscape of soft rolling hills, cloaked with moorland grasses in the higher parts, and lush green pastures and herb rich meadows on the lower slopes	Beech woodland Ancient woodland Hay meadows and herb rich pastures e.g. Barn Gill Meadow SSSI and Landcliff Cross Meadow SSSI Raised mire e.g. Hesley Moss SSSI & White Moss SSSI Roadside verges	Rocky slopes and outcrops Millstone grit and limestone Glacial gravel and clay deposits	Stone circles – sheep folds Isolated farmsteads and barns Dry stone walls		

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
M. Forestry and Reservoir	Man made features dominate the character and feel of these areas.	Open water Coniferous woodland Gold crest, coal tit, and siskin Broadleaved woodland Reservoir draw down zones are important habitats for a specialised flora Breeding and over wintering wildfowl and waders. Black headed gull colony.	Millstone grit and limestone Glacial gravel and clay deposits Rocky outcrops Glacial diversion gorges	Dry stone walls Relic farmsteads Drowned village of Dale Head Disused railway	Stocks Reservoir and Barley Reservoir Reservoir 'furniture' such as dams, stone walls, roads and slipways and buildings Gisburn Forest - coniferous plantation Pastoral fields	Church at Stocks Reservoir

Characteristic	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
N. Farmed ridges	Relatively low in comparison to the Bowland Fells - ridges have elevations of 140-230m and distinctive rounded profiles. Long, open views across surrounding lowlands.	Broadleaved woodland	Gritstone outcrops form the ridges Boulder clay	Designed landscapes and country houses e.g. Quernmore Park Hall	Intensive farming - pasture used by beef and dairy cattle	Linear settlements

B.1.2 Ecosystem services

Ecosystem services are the range of goods and services provided by natural ecosystems from which humans derive benefit . The Millennium Ecosystem Assessment identified four types of ecosystem services:

- Provisioning services such as food and forestry, energy and fresh water;
- Regulating services such as climate regulation and water purification;
- Supporting services such as soil formation and pollination; and
- Cultural services such as recreation, inspiration and sense of place.

Soil formation

Soils underpin landscape character, a range of ecosystem services and biodiversity. Soil production underpins many ecosystem services, including water resources and quality, food production and carbon storage. Soil type, depth and fertility also contribute to the biodiversity and character of an area, supporting different habitat types. Soil also plays an important role in the historic development of landscape, often determining which areas were farmed and settled.

Eight different soil types have been identified in the Forest of Bowland AONB using Soilscapes :

- Naturally wet, loamy and clayey floodplain soils;
- Slow permeable, seasonally wet, acid loams and clay;
- Freely draining floodplain soil;
- Freely draining slightly acid loamy soils;
- Peaty, slowly permeable, wet, very acid upland soils;
- Very acid loamy upland soils: wet peaty surface;
- Blanket bog peat soils; and
- Shallow lime rich soils over chalk or limestone

Food production

The damp climate of the north west of England and soil types which support grassland habitats (especially boulder clay, brown earths and alluvial gleys) means that the Forest of Bowland AONB is particularly suitable for livestock farming. Sheep and beef farming are found in upland areas where acid grassland is used for grazing (see Figure B.5). Lowland pasture supports dairying, particularly in the Ribble and Lune valleys. The lowland areas of the Forest of Bowland AONB also support pastures and meadows which are used for hay and silage production as well as growing fodder crops. Boundary features such as hedgerows and walls are associated with farming and there are a small number of food processing units in the AONB.

Heather moorland in the upland areas of the AONB is used for grouse, pheasant and partridge shooting. Infrastructure associated with shooting includes access tracks, shooting butts, cabins and feeding stations

Timber

The main commercial forestry plantation in the AONB is Gisburn Forest but there is also a small amount of coniferous forest plantation on Thrusgill and Longridge Fells, and in the Brenand and Whitendale valleys.

Energy

Currently, relatively little energy is produced in the AONB. There is a small amount of short rotation coppice which is grown for biomass energy production and there are a few farms which use anaerobic digestion to produce energy. Historically coppice and charcoal production took place in wooded valleys such as Roeburndale. Work is being carried out looking at the feasibility of hydro power in the AONB and a number of potential sites have been identified. A small wind farm exists on Caton Moor, and there is increasing pressure for other wind farm development within and around the AONB boundary.

Figure B.4 - Sheep gathering

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Water resources and quality

Freshwater resources in the Forest of Bowland AONB are provided by a number of large rivers which cross the area and there are abstractions from the rivers Lune, Hodder, Wyre, Roeburn, Ribble and Hindburn. There are also many flushes and springs which occur at the interface between gritstone and shale.

Semi-natural habitats can contribute to the provision of freshwater resources by retaining water in catchments. Some wetland habitats also contribute to improved water quality by providing a filtering function. United Utilities manage large areas of upland habitats in the Forest of Bowland, including peat bog and woodland, for their water resource and quality benefits.

There are also a number of man-made assets in the Forest of Bowland AONB which contribute to the provision of fresh water. Reservoirs such as Stocks, Barley and Langthwaite provide water for much of the Fylde area of Lancashire.

Minerals

Historically, limestone, shales and sandstone rocks have been quarried in the Forest of Bowland and there are a number of small scale quarries and lime kilns in the landscape. Present day limestone quarrying is found to the east of Clitheroe. Related industry such as cement works are also found in the area. Lead was also mined historically in the limestone areas of the AONB, in the Hodder Valley and in the Trough of Bowland (Smelt Mill).

Carbon storage

Soils and biomass can perform an important role in storing and sequestering carbon. Peat soils and the blanket bog habitat they support are play a particularly significant role in storing carbon but other semi-natural habitats such as woodlands, wetlands and grasslands also act as carbon stores.

Flood alleviation

The wide, unconstrained floodplains of the rivers which run through the Forest of Bowland AONB provide a flood storage function, alleviating the risk of flooding during periods of high flows. Semi-natural habitats also play a role in flood alleviation as they slow flows and retain water in the catchment before it reaches rivers and streams. Artificial flood basins have been constructed at Garstang and Catterall to store water during flood events. Blanket bogs on the moorland plateaux act as water retention areas when they are fully functioning, and can reduce run off and erosion, and flooding lower down the catchment as they provide a slower release of rainwater from the uplands.

Pollination

This is a critical service without which many plants, and the animals and humans that depend on them would find it difficult to reproduce. Although some plants are pollinated abiotically (though non-biological processes such as the wind) many plants rely on invertebrate pollination to set seed. Good habitats for pollinating insects are those with rich sources of nectar. In the Forest of Bowland AONB these include herb-rich hay meadows, pasture, woodland, parkland, upland heath and waterbodies.

Sense of place and inspiration

Sense of place very much depends on how individuals perceive and relate to a landscape. Particularly iconic landforms, habitats and historic environment features can all contribute to the distinctiveness of an area which can play an important part in determining a sense of place. In the Forest of Bowland, distinctive features include the contrast between the uplands and the lowlands, the wide open spaces of the moors and fells, the wooded river valleys which radiate out from the centre and country houses and their estates.

The landscape of the Forest of Bowland has provided inspiration to painters and authors. The Lune valley is the setting for art works by Turner and Tolkien supposedly wrote much of the Lord of the Rings whilst staying at Stonyhurst College.

Tranquillity

The dispersed nature of settlements, quiet networks of country lanes, low population density and extensive pastoral farming all contribute to the tranquillity of the AONB. Evidence of humans is scarce in some upland areas and the open moorland is often very peaceful. Even in lowland areas, farming and settlements detract little from the tranquillity of the place.

Recreation

The Forest of Bowland AONB provides a place for quiet recreation and enjoyment of the natural environment. Much of the uplands are Open Access areas under the Countryside and Rights of Way (CRoW) Act (2000) and the heather moorlands are used for game shooting and fell running. Gisburn Forest is popular for mountain biking (see Figure B.6), horse riding and walking. There is a network of rights of way throughout the AONB, including sections of long-distance paths such as the Ribble Way, Pennine Bridleway, the Journey through the Centre of the Kingdom, the Lancashire Cycleway and the North Lancashire bridleway. A number of trails have been developed for use by all-terrain wheelchairs (trampers).

Prominent landforms such as Pendle Hill, Bowland Knotts, Clougha Pike and the Trough of Bowland attract visitors, as do historic houses, estates, abbeys, monuments and Clitheroe castle. Visitor centres such as Beacon Fell also attract people. Visitor facilities such as car parks and toilets are provided at many of these sites and accommodation can be found in villages and outlying farms. There is a network of lanes throughout the AONB and some around Slaidburn, Chipping and Downham have been designated as Quiet Lanes.

Fishing is a significant recreation activity in the Forest of Bowland. Stocks Reservoir is one of the largest trout fisheries in the UK and salmon, sea trout and brown trout can be fished in the rivers Ribble, Hodder, Wyre and Lune (see Figure B.7).

Figure B.5 - Mountain bike trails in Gisburn Forest ©Jon Sparks

Figure B.6 - Fly fishing on a Bowland river ©Graham Cooper

Knowledge

There are a number of assets in the Forest of Bowland which contribute to the scientific and historical understanding of the area and beyond. Approximately 160 square kilometres (13%) of the AONB has been designated as a Site of Special Scientific Interest (SSSI) for their biological or geological importance (or both). In addition to SSSIs, there are a number of sites designated as Regionally Important Geological Sites (RIGS) and a large Special Protection Area (SPA) is an international designation, for birds.

There are historic environment assets throughout the AONB which contribute to our understanding of the development of the area. Buried archaeology is found particularly in peat soils and floodplains and historic structures such as castles, quarries, lime kilns (see Figure B.8) and vernacular farm buildings are found throughout the lowlands.

Figure B.7 - Lime kiln in the Trough of Bowland

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Table B.2 - Assets contributing to ecosystem services in the Forest of Bowland AONB

Ecosystem Service	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
Soil formation	Range of soil types in AONB (identified from Soilscapes)		Underlying geology – limestone, millstone grit, sandstone and shales Glacial drift deposits Alluvial deposits in river valleys and floodplains Soil types: Naturally wet, loamy and clayey floodplain soils; Slow permeable, seasonally wet, acid loams and clay; Freely draining floodplain soil; Freely draining slightly acid loamy soils; Peaty, slowly permeable, wet, very acid upland soils; Very acid loamy upland soils: wet peaty surface; Blanket bog peat soils; Shallow lime rich soils over chalk or limestone.			

Ecosystem Service	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
Food production	Sheep and beef farming in the uplands. Dairying in the Ribble and Lune Valleys and much of the lowland farmland.	Acid grassland for grazing Lowland pasture – fertile in-bye	Soil types which support grassland (boulder clay, brown earths, alluvial gley)	Ancient hedgerows and walls Historic farm buildings and barns	Damp climate	Boundary features e.g. hedgerows and dry stone walls Modern farm buildings Cheese making units – e.g. Leagram, Dewlay
	Grouse, pheasant and partridge shooting	Heather moorland Wooded valleys				Access tracks Shooting butts and cabins, feeding stations
Timber	Areas of plantation forest	Coniferous forest plantation woodland at Gisburn and on Thrusgill and Longridge Fells.				
Energy	Production of renewable energy from biomass	Woodland Short rotation coppice				

Ecosystem Service	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
Water resources and quality	Provision of water resources for drinking water supply and for domestic and farming use. Filtering of water to remove impurities	Upland habitats – catchment woodland maintained by United Utilities Peat habitat Wetland habitats – filtering function	Interface between gritstones and shales has resulted in many of the flushes/springs Peat soils - retaining water for long term release, filtering function Waterlogged moorland soils	Disused pipes and underground aqueducts Spring line farmsteads	Stocks Reservoir, Barley Reservoir and Langthwaite reservoir (filled from River Lune intake at Caton) Pipeline transfer between Lune and Wyre Surface water resources - intakes on major rivers inc. Lune, Hodder, Wyre, Roeburn, Ribble and Hindburn Flushes and springs e.g. Calder Valley, below Hawthornwaite Fell (i.e. Black Clough to the Marshaw Wyre) and within the Brennand Valley	Haweswater and other aqueducts have overground 'furniture' e.g. gates, inspection chambers and pipes over rivers

Ecosystem Service	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
Minerals	Quarrying of limestone and related industry e.g. cement works	Important bat roosts in some lime kilns and quarries, also ferns, amphibians	Limestones, shales and sandstone rocks. Exposed gritstone outcrops from Bowland Knotts through Eldroth to the Ribble near Settle.	Small scale limestone quarries and limekilns remain visible in Whitewell and Slaidburn areas.		Cement works Larger scale quarries east of Clitheroe.
Climate regulation	Carbon storage	Peat habitats – blanket bog Woodland habitats Grazing marsh Permanent grassland	Peat soils			
Flood alleviation	Contribution to reduction of flood extent due to flood water storage	All semi-natural habitats (particularly wetland habitats and blanket bog)	Floodplains of the rivers Ribble, Lune and lower Hodder			Flood basins constructed at Garstang and Catterall
Pollination	Habitats for invertebrates	Good habitats and nectar sources for pollinating insects and invertebrates - herb-rich hay meadow and pastures; woodland; parkland; upland heath and waterbodies				

Ecosystem Service	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
Sense of place and inspiration	The unique feel and appearance of a place that makes it different to other places	Mosaic of habitats – meadows, woodlands, rivers	Landforms and contrast between them - fells and fringe River valleys – Lune valley was a setting of art works by Turner Outcrops	All historic environment assets Historic villages – vernacular building styles Country houses and estates		Views Tolkien wrote much of Lord of the Rings here
Tranquillity	Sense of peace and quiet	Wooded river valleys Parklands Open moorland		Historic villages and hamlets	Undulating lowland farmland	

Ecosystem Service	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
Recreation	Access to the AONB for recreational pursuits and tourism	Moorland habitats – red grouse shooting and open access land Woodland – veteran trees Rivers and open water Nature reserves and designated sites Bird species e.g. hen harrier, merlin and ring ouzel, wading birds.	Prominent landforms e.g. Pendle Hill, Ward's Stone, Bowland Knotts and Clougha Pike	Historic routeways Estates and country houses e.g. Browsholme Hall, Pendle Heritage Centre Cistercian monastery at Sawley Bleasdale Circle Castles e.g. Clitheroe castle Cromwell Bridge Churches e.g. Dalehead church, Slaidburn, Mitton etc	Rivers Ribble, Hodder, Wyre and Lune used for fishing (salmon, sea trout and brown trout) Stocks Reservoir Thermals – gliding and paragliding and hot air ballooning	Constructed paths, riverside walks, long distance routes (Ribble Way, Pennine Way and Pendle Way, Wyre Way, Lunesdale Walk, Lune Valley Ramble, Journey through the Centre of the Kingdom) 7 GPS trails Promoted trails (web downloads) Tramper Trails(all-terrain wheelchairs) Wyresdale Wheels Bowland Experience Gisburn Forest mountain bike trails, walking and horse riding with associated car parks. Lancashire Cycleway

Ecosystem Service	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
						North Lancashire Bridleway and associated networks. Shooting tracks Network of roads and lanes – public transport Longridge Fell moorland and forestry (walking, cycling, fell running and horse riding. CRoW Act 2000 Access Land (walking and fell running). Car parks, lay-bys and village car parks Designated Quiet Lanes around Slaidburn, Chipping and Downham Settlements with visitor facilities Views Visitor centres and country parks e.g. Beacon Fell

Ecosystem Service	Brief Description	Contributing Assets Habitats and species	Geodiversity	Historic Environment	Natural Resources	Other landscape features
Knowledge	Assets which contribute to our scientific and historic understanding of the area	All habitats (particularly the 162 sq km designated as SSSI)	Exposed outcrops (SSSIs and RIGS)	Buried archaeology Field patterns and boundaries Castles Mining remains and lime kilns Country houses Prehistoric settlements		

B.1.3 Biodiversity

The Forest of Bowland AONB supports a wide range of Biodiversity Action Plan (BAP) habitats including:

- Blanket Bog;
- Upland heath;
- Lowland Meadows (see Figure B.9);
- Lowland dry acid grassland;
- Lowland calcareous grassland;
- Purple moor grass and rush pasture;
- Upland Hay Meadows;
- Hedgerows;
- Lowland mixed deciduous woodland;
- Upland mixed ashwoods;
- Upland oakwood;
- Wet woodland;
- Upland flushes, fens and swamps;
- Rivers;
- Ponds; and
- Wood pasture and parkland.

Figure B.8 – Orchids in Myttons Meadows ©Jon Hickling

In addition to BAP habitats, roadside verges are important habitats in the Forest of Bowland AONB.

Habitats in the AONB support a range of BAP species (see Table B.3 below), as well as a number of important but non-BAP species (see Table B.4 below).

Table B.3 - BAP species found in the Forest of Bowland AONB

Species group	BAP species
Birds	Twite, red grouse, curlew, grey partridge, ring ouzel, skylark, lapwing, spotted flycatcher, songthrush, herring gull, cuckoo, wood warbler, linnet
Fish	European eel, Atlantic salmon, brown/sea trout, brook lamprey (specifically in the Ribble and Loud, Mearley, Wigglesworth sub-catchments)
Herpetiles	Adder, slow worm, common lizard
Non-vascular plants	River jelly lichen
Terrestrial invertebrates	Large heath butterfly
Terrestrial mammals	Brown hare, otter, pipistrelle bat, water vole

Table B.4 - Other important (non-BAP) species in the Forest of Bowland AONB

Species group	Species
Birds	Hen harrier, peregrine, merlin, short eared owl, golden plover, lesser black backed gull, redshank, snipe, grey wagtail, dipper, common sandpiper
Non-vascular plants	Sphagnum
Vascular plants	Greater butterfly orchid, cloudberry, bog rosemary, pale forget-me-not, chickweed wintergreen, ivy leafed bellflower, hay scented buckler fern, filmy ferns, birdseye primrose, grass of Parnassus
Terrestrial invertebrates	Small pearl bordered fritillary, large heath butterfly, *Clubonia norvegica* (a rare spider)
Terrestrial mammals	Badger, noctule bat, brown long eared bat, roe deer

B.2 Step 3

In this section the results of the vulnerability assessment are summarised. The vulnerability of the assets identified in Step 2 of the method to the impacts of climate change was identified. Each asset was rated as more vulnerable, moderately vulnerable or less vulnerable. The assets were grouped under the following headings:

- Habitats and species;
- Geodiversity and soils;
- Historic environment;
- Natural resources; and
- Other landscape features.

B.2.1 Habitats and species

More vulnerable

Blanket bog is likely to be more vulnerable due to its sensitivity to changing temperatures and hydrology. The surface layer of peat is sensitive to oxidation and decay during hotter, drier summers and there is already evidence of erosion and the formation of peat hags in the Forest of Bowland. Wetter winters and an increase in intense rainfall events could lead to bog burst. The capacity of blanket bog to adapt to these impacts may be compromised by the legacy of historic drainage, burning and grazing which has left the habitat in a poor condition in places. However, many blanket bog sites are now in management, either through Higher Level Stewardship (HLS) or United Utilities' Sustainable Catchment Management Programme (SCaMP) so the ability of these areas of blanket bog to adapt may be greater.

Purple moor grass and rush pasture is sensitive to lowering of the water table and the drying up of springs and flushes during hotter, drier summers. This could lead to a loss of mire species and an increase in scrub and woodland species. Purple moor grass and rush pasture is also sensitive to wild fire, the risk of which may increase during hotter summers. This habitat is highly fragmented in the Forest of Bowland due to past agricultural activity. This, along with competing demands for water resources, may reduce the capacity of the habitat to adapt to climate change.

Upland hay meadows are sensitive to changes in species composition as a result of a longer growing season. Montane plant species may lose climate space and be replaced with lowland species whose range is extending. Upland hay meadows could also be sensitive to changes in agricultural practice as a result of climate change: for example an increase in intense rainfall events could prevent cutting. The legacy of past agricultural practice such as fertiliser application and early harvesting may reduce the adaptive capacity of this habitat in parts of the Forest of Bowland. Areas which are sensitively and appropriately managed through HLS may have greater capacity to adapt.

Wet woodland is considered to be more vulnerable as it is dependent on the availability of groundwater and flushes. During drier summers springs and flushes may dry up and seasonal cycles of wetting and drying could alter soil chemistry. If areas dry up, wet woodland could be replaced by more mixed deciduous woodland species. The lack of connectivity of this habitat within the Forest of Bowland may reduce its ability to adapt to climate change.

Upland springs and flushes are very sensitive to drought and drying up during summer. The adaptive capacity of springs and flushes is likely to be limited as the habitat is constrained by topography.

Ponds and open water habitats are sensitive to drying out in summer, potentially leading to a concentration of pollutants, loss of fish spawning habitat and a loss of connectivity with other freshwater habitats. Higher water temperatures may lead to a greater frequency and duration of algal blooms. Wading birds are likely to be very sensitive to these changes in habitat. Some pond taxa are capable of rapid dispersal but a lack of connectivity may reduce their ability to adapt. Currently, rural payment schemes exclude ponds, reducing the capacity to manage them in order to reduce vulnerability.

Whilst **lowland deciduous woodland** is considered moderately vulnerable, **ground flora** associated with this type of woodland is considered more vulnerable. This habitat is found along watercourses and ground flora is sensitive to erosion and sedimentation. The adaptive capacity of ground flora is low as it requires suitable habitat to become established before it can move. Where rights of way cross this habitat, ground flora is also sensitive to trampling, exacerbating vulnerability.

Moderately vulnerable

The wet elements of **lowland meadows** are sensitive to drought and a possible change in species composition to more drought-tolerant species. The dry elements of this habitat are sensitive to flooding which could prevent cutting. However, it is thought that this habitat will persist although may become less diverse as a result of climate change.

Lowland calcareous grassland is likely to be sensitive to drought and parching, leading to erosion and damage to lower plant assemblages. However, this habitat is found on drought-prone soil and is already partially adapted to dry conditions. The distribution of calcareous soils in the Forest of Bowland may limit the ability of the habitat to move in response to climate change.

The majority of **woodland types** in the Forest of Bowland (excluding wet woodland) are considered moderately vulnerable to the impacts of climate change. Trees are sensitive to stress caused by drought, changes in temperature and pests and diseases. Sudden oak death has not yet reached the Forest of Bowland but warmer temperatures could see it move northwards, potentially affecting upland oakwoods. Competition from more southerly species may increase as a result of climate change, for example, Holm oak may become more prevalent in lowland mixed deciduous woodland and there may be an expansion of 'dry' forms of upland ash in upland mixed ashwoods. The age of trees is likely to be an important factor in determining the adaptive capacity of woodlands: stands of a uniform age may have lower adaptive capacity than those with a range of ages and veteran trees may be most vulnerable. The degree to which woodland is managed may also affect its capacity to adapt to climate change.

Rivers and streams are sensitive to drought and low flows which can lead to reduced habitat volume and poor water quality. Wetter winters and more frequent intense rainfall events may lead to an increase in flooding which can cause bank erosion and sedimentation. However, rivers and streams in the Forest of Bowland remain relatively natural, unconstrained systems and have room to move in response to climate change. Pressure on some surface water resources has also lessened in recent years as abstractions from the river Brennand, for example, have been reduced, increasing the capacity of that river to adapt to climate change.

Less vulnerable

Upland heath is considered less vulnerable to climate change as it is relatively robust to a wide range of climatic conditions. It is possible that heathland vegetation may increase in the Forest of Bowland, particularly if blanket bog areas dry out. However, it may become more susceptible to heather beetle attack and uncontrolled burns during hotter, drier summers.

Lowland dry acid grassland is generally well adapted to dry conditions although invertebrates and bird species associated with the habitat may be more sensitive than flora.

Hedgerow habitats are likely to remain in the Forest of Bowland AONB although their species composition may change. Hedgerows are likely to be more vulnerable to changes in agriculture than direct impacts of climate change however, opportunities exist to manage hedgerows through agri-environment schemes.

Coniferous forest shares the same sensitivities as other woodland types (i.e. sensitive to drought and pests and diseases) but is highly managed with scope for management and planting to be changed in response to climate change.

Roadside verges are also highly managed habitats which are likely to have a relatively high adaptive capacity.

B.2.2 Geodiversity and soils

More vulnerable

Peat soils are likely to be the most vulnerable to climate change as they are highly sensitive to drying out during hot, dry summers and gullying and hagging during wetter winters. Some peat soils in the Forest of Bowland are in poor condition due to historic drainage, burning and over-grazing, reducing their capacity to adapt to climate change. The difficulty of retaining water on upland slopes also makes it difficult to manage peat soils by re-wetting.

Moderately vulnerable

Clay soils are likely to be moderately vulnerable to climate change as they are sensitive to waterlogging and compaction when wet.

Shallow lime rich soils are sensitive to drying out and oxidation during hotter, drier summers, leading to erosion and loss. The shallow nature of these soils reduces increases their vulnerability.

Isolated hills and reef knolls may be sensitive to increase rates of weathering and erosion as a result of hotter, drier summers and warmer, wetter winters. Calcareous material has relatively low resistance to erosion; hence the capacity of these features to withstand an increase in erosion is low.

Less vulnerable

Freely draining soils in the Forest of Bowland are thought to be relatively less vulnerable to climate change as they are already drought-prone. However, where these soils are found on steeply sloping land their vulnerability may be higher as they are likely to be shallow.

Most **geological features** in the Forest of Bowland (e.g. terraces and escarpments, boulders and erratics and rocky outcrops) may be sensitive to an increase in erosion and increased vegetation growth. However, most of these features are relatively hard, resistant rocks such as gritstone which has a higher adaptive capacity than softer rocks such as shale or limestone.

Geomorphological processes that form features such as river and stream valleys, braided river systems, waterfalls and oxbow lakes are likely to be less vulnerable to climate change as they are generally able to operate naturally in the Forest of Bowland. However, the form of rivers may alter in response to wetter winters and drier summers. Most of the rivers and streams in the AONB are unconstrained by development and flood defence structures, allowing room to move in response to climate change.

B.2.3 Historic environment

More vulnerable

Buried archaeology, particularly in peat soils, is very sensitive to changes in rainfall. Drier summers may lead to drying out and cracking of soils, as well as fires which could lead to exposure of buried assets. However, wetter winters and extreme rainfall events may lead to changes in soil chemistry as well as crystallisation and dissolution of salts which may damage archaeology. Peat soils preserve archaeology anaerobically and buried assets have a low tolerance of change in soil conditions before damage occurs. There is also little capacity for management of buried archaeology as once it is damaged it cannot be replaced. Re-wetting of peat soils is particularly difficult on sloping ground.

The vulnerability of individual habitats and species which form part of **designed landscapes** (which include ornamental gardens, parkland and landmark trees) can be seen in the habitats and species vulnerability assessment. However, the vulnerability of individual elements can be more significant in the context of designed landscapes as historic value lies in the particular design, species choice and layout of these places. Designed landscapes are likely to be particularly vulnerable to changes in species composition and loss of veteran trees.

Moderately vulnerable

Most **historic buildings** (including farm buildings and barns, domestic buildings, parkland structures, churches (see Figure B.9) and kilns) are thought to be moderately vulnerable to the impacts of climate change. Buildings are particularly sensitive to repeated cycles of wetting and drying which can lead to an increase in weathering of surfaces. Drought conditions can lead to drying and cracking of soils, potentially leading to subsidence. Wetter winters may increase the moisture content in the building fabric, possibly leading to decay of stonework or timber. The capacity of the building to adapt to these impacts may depend on the building materials: buildings made of harder, more resistant gritstone may have higher adaptive capacity than those made out of softer limestone. Buildings which are still in use are also likely to have greater management capacity.

Figure B.9 - Quernmore church and school ©Graham Cooper

Historic boundary features such as dry stone walls may be sensitive to ground instability caused by drought or flooding. Large seasonal variation in temperature may also affect walls and there is anecdotal evidence that there has been a high number of wall collapses following cold winters. The adaptive capacity of walls may depend on their current condition. Many walls in the Forest of Bowland are in a good state of repair and some are covered by HLS agreements, increasing their adaptive capacity.

Historic field patterns are likely to be vulnerable to soil erosion caused by hotter, drier summers and warmer, wetter winters. An increase in vegetation growth as a result of longer growing seasons could obscure field patterns although this would be unlikely to result in their destruction. Motte and bailey castles and historic quarries are also likely to be subject to greater rates of soil erosion and vegetation growth.

B.2.4 Natural resources

More vulnerable

Fishing is important to the economy in the Forest of Bowland but fisheries are likely to be vulnerable to climate change. Warmer water and low flows in summer could reduce water quality and habitat for salmon, sea trout and brown trout. Water quality may also deteriorate as a result of pollutants and sediment washed into watercourses during flood events. Sedimentation can have a negative effect on fish spawning habitat. If fish fail to migrate or breed successfully in response to these changes, fisheries in the Forest of Bowland could be depleted and it could be difficult to establish new stocks.

Moderately vulnerable

In-bye pasture is sensitive to drying out in summer and waterlogging during wetter winters and extreme rainfall events. However, as this land is managed for grazing, there should be capacity to adapt to changing conditions through altering stocking levels, types and timing.

Like most woodlands, areas of managed **planting and coppicing** are sensitive to stress caused by drought and pests and diseases. Plantations are likely to be of a uniform age, potentially increasing their vulnerability. However, they are highly monitored and managed systems so pests and diseases are likely to be spotted early and capacity to manage species composition is high.

Surface water intakes from rivers in the Forest of Bowland are sensitive to low flows in summer. This reduction in water supply may coincide with an increase in demand as summers become hotter. However, flows are protected by hands-off-flow conditions which prevent water levels becoming too low, increasing adaptive capacity.

Less vulnerable

Reservoirs and associated infrastructure may be sensitive to lower water levels in summer, leading to increased pressure on water supply. Wetter winters and intense rainfall events may lead to an increase in flood risk although there is capacity to manage this through altering reservoir operating curves. The safety margins built into these structures are considerable: they are designed to cope with 1 in 1000 year events. Also, as reservoirs are highly managed systems, there is considerable capacity to manage them in response to climate change (see forthcoming Defra guidance on the impacts of climate change on dams and reservoirs).

Quarries may be sensitive to an increase in vegetation growth which may obscure active and inactive faces. However, as active quarries are intensively managed, they are likely to be able to adapt to this impact.

B.2.5 Other landscape features

More vulnerable

Footpaths and bridleways are particularly sensitive to waterlogging and erosion during wet winters and intense rainfall events. There are already paths within the Forest of Bowland AONB which are experiencing damage during wet winters. Climate change may also result in an increase in demand and different usage patterns, potentially exacerbating erosion problems. Adaptive capacity is largely dependent on soil types; paths in the uplands on peat soils are particularly vulnerable to waterlogging whereas paths on free-draining soils may be more vulnerable to erosion during drier summers. The low density of paths in upland areas may reduce their adaptive capacity as they are likely to become more congested if demand increases. Paths which are already well managed are likely to have greater adaptive capacity although costs may rise.

Moderately vulnerable

Fords are sensitive to flooding during wetter winters or extreme rainfall events and this could prevent them from being used.

A number of types of buildings, including **industrial buildings and visitor centres** could be vulnerable to the impacts of climate change. Buildings and their uses are likely to be sensitive to flooding as well as increased rates of weathering and erosion. Subsidence caused by drying and cracking of soils could also be a problem for buildings. As noted in Section 5.4, the type of material used to construct buildings is likely to affect their adaptive capacity but as buildings in this category are likely to be in use, their adaptive capacity is high.

Less vulnerable

Small man-made features such as grouse butts and cairns and stone towers may be sensitive to increased weathering and erosion as well as increased vegetation growth which could obscure them. However, they are relatively easy to re-create.

Shooting tracks may be sensitive to similar impacts as footpaths but they do not experience high usage so are considered to be less vulnerable. Whilst road surfaces may be sensitive to erosion, the network of minor roads and lanes in the Forest of Bowland is likely to have high adaptive capacity due to the availability of alternative routes and current management.

Settlements as a feature in the landscape are unlikely to be sensitive to climate change and are likely to remain in their present locations. Individual historic buildings may be vulnerable though, (see Section 5.4).

Post and wire fences and modern farm buildings may be sensitive to subsidence although as they are already highly managed and relatively easy to replace, they are considered less vulnerable.

B.3 Step 4

In this section, the implications of the vulnerabilities identified in Step 3 are summarised. Implications for biodiversity have been integrated into the headings of landscape character. The paragraphs below describe potential changes as a result of the vulnerability of assets to direct impacts of climate change, in the absence of adaptation actions.

B.3.1 Landscape character

A. Moorland plateaux

The landscape character of the moorland plateaux areas may change significantly as a result of climate change. Whilst the underlying geology of the area and shape of the land is likely to be relatively insensitive to climate change, many of the assets which contribute to landscape character are considered to be more vulnerable e.g. blanket bog habitat and peat soils. Changes in habitat mosaics and species composition in these areas could alter the appearance of the landscape and the upland character could gradually be replaced with a more lowland feel. The more transient features associated with this landscape type such as grouse butts and cairns may be less vulnerable as they may be re-created although their historic significance may be lost.

B. Unenclosed moorland hills

The distinctive rounded hills and the unenclosed feeling which results from a lack of dry stone walls are likely to remain characteristic of these areas. An increase in demand for recreation in the AONB could see an increase in human activity in these areas although they are likely to remain marginal for farming. The upland heath and blanket bog habitats which are typical of these areas are likely to be vulnerable to climate change. There may be a shift towards more lowland species and encroaching bracken could have a significant impact on landscape character unless managed. Trees are likely to remain features in the landscape although changes in species composition in oak and ashwoods may change the appearance of wooded areas. These changes in habitats could lead to a decline in bird species currently associated with these areas such as skylarks, red grouse, hen harrier and curlew.

C. Enclosed moorland hills

The implications of climate change for the landscape character of these areas are likely to be similar to those experienced in unenclosed moorland hills areas. Habitats and species compositions may become more lowland in character. Some of the features which contribute to the historic character of these areas such as relict boundaries and field patterns may become less visible in the landscape as they are obscured by vegetation or become eroded. This may lead to a reduction in the sense of connection to the past in these landscape areas with the possible loss of historic knowledge.

D. Moorland fringe

The moorland fringe character type may be particularly vulnerable to landscape change as it becomes squeezed between the fells which are likely to be protected due to their SSSI designation and increased production required from more lowland areas. Climate change could see these areas becoming drier, although the damp pasture and meadow habitats are likely to remain important for grazing as lowland areas are likely to dry out more. It is possible that agriculture will increase here as climate becomes more suitable and upland areas become less marginal. Historic structures may be vulnerable to direct impacts of climate change including erosion and subsidence but possibly more significant may be the loss of these features as a result of increasing agricultural intensification. However, it is likely that the enclosed character of these areas will persist.

E. Undulating lowland farmland

The agricultural character of these areas is likely to persist and may increase in significance. Ancient woodland and hedgerows are features of the landscape which may be vulnerable to climate change. Any loss of trees or wooded areas would affect the character of these areas as they are significant features in a largely farmed landscape. There is strong evidence of human activity in these areas and historic buildings and structures may be vulnerable to damage from seasonal cycles of wetting and drying. Some historic features such as relict boundaries and field patterns may become

less visible as they are obscured by vegetation or become eroded. However, modern human features such as settlements, roads and small scale food processing industries are likely to remain in these areas.

F. Undulating lowland farmland with wooded brooks

Drier summers could lead to low flows within lowland streams whilst higher winter rainfall and more intense rainfall events could lead to an increase in flood events. These changes in seasonal precipitation could lead to habitat change within brooks, with wet woodland particularly sensitive to drying out in summer. Other types of woodland in these areas (ash and oak woodland) may also see changes in species composition and changes in ground flora as conditions become drier in summer. This could result in an overall change towards mixed deciduous woodland, altering the character of these areas. Wet grassland is also vulnerable to changes in seasonal precipitation, becoming drier in summer and at risk of flooding in winter.

G. Undulating lowland farmland with parkland

These lowland areas are characterised by historic estates, parkland and designed landscapes. Historic buildings may be vulnerable to climate change, particularly changes in seasonal cycles of wetting and drying which could alter their external appearance. Veteran trees and areas of ornamental planting may be particularly vulnerable to climate change and their loss could have significant impacts on the character of these areas. Grassland habitats within these areas may also be vulnerable to climate change as they are found on well drained soils which may be susceptible to drying out during warmer summers. Characteristic reef-knolls may be vulnerable to an increase in the rate of erosion as a result of summer drought and more extreme rainfall events. Changes in the appearance of parkland areas, including the loss of individual trees may be of particular importance because they have been designed and it may be difficult to re-create these landscapes without losing their historic and cultural significance. An increase in demand for recreation in the AONB could see an increase in visitors to historic estates and parkland.

H. Undulating lowland farmland with settlement and industry

In these areas pastoral fields are punctuated by transport corridors and relatively large urban areas and relatively industrial compared to other landscape character areas. Quarries and exposed rock outcrops may become obscured by increasing vegetation growth. This could affect the knowledge value of SSSI features as geological sequences become less visible and increase the maintenance requirements at active quarry sites. Historic structures may be vulnerable to climate change and their appearance may change. However, they are likely to remain features in the landscape as many of them are still in use. Modern human features in the landscape such as roads and railways are likely to be affected by the impacts of climate change, including flooding, drought and subsidence although settlements and industry are likely to remain prominent in the landscape.

I. Wooded rural valleys

The geological features that are characteristic of these areas, including valleys, waterfalls and river terraces may experience an increase in erosion, particularly during high flows. High flows could cause damage to historic structures associated with the streams such as mills, sluices and packhorse bridges, potentially altering the historic landscape character of these areas if they are lost. In summer there may be less water in rivers and streams, changing the appearance of these areas to drier valleys. River habitats may be affected by low flows in summer, potentially leading to a decrease in water quantity and quality. Water quality may also deteriorate following flood events which wash in sediment, nutrients and organic matter. Woodland habitats found on the valley sides and fringing the streams may see a change in species composition with a shift towards more drought tolerant trees such as beech. Wet woodland, found in the valleys, may be vulnerable to drying out in summer and there could be a shift towards mixed deciduous woodland. There may also be more opportunity here for invasive species such as Himalayan Balsam to move into susceptible areas, especially if soil is left bare. Changes in species composition of woodland and riverine habitats would not only affect biodiversity but could change the appearance and character of these areas.

J. Valley floodplains

As a feature in the landscape, floodplains are likely to be relatively insensitive to the impacts of climate change although soft alluvial deposits may be more easily eroded. Associated features such as river terraces, banks, shingle margins and oxbow lakes are sensitive to seasonal changes in erosion processes caused by high flows in winter, extreme rainfall events and low flows in summer. Changes in flow regimes could lead to changes in the shape and course of rivers through their floodplains. Rivers are dynamic systems and have changed their course over time but there may be implications for farmland and views in the AONB.

It is likely that wetland habitats will become drier in summer as rainfall is projected to decrease. This could lead to a change in vegetation with a move towards drier grassland species. Lowland raised bogs are particularly vulnerable to drying out and could be lost from these areas. The loss of these habitats would not only affect the appearance of these areas but could affect their historic character. A long history of human settlement in these areas has resulted in a concentration of historic environment assets such as motte and bailey castles and buried archaeology which could be lost if soils dry out and are more easily eroded.

K. Drumlin fields

The drumlins which are characteristic of this landscape area are likely to be relatively insensitive to the impacts of climate change. However, the habitats and land uses which occur on top of the drumlins may be vulnerable. Woodland on the steeper slopes may be vulnerable to drought, particularly ancient woodland where trees are likely to be stressed during dry summers. This could lead to a change in species composition, changing the colour and texture of the slopes. On the lower slopes, wetland habitats such as tall herb and swamp vegetation and remnant mires are also likely to be sensitive to drying out, leading to a shift towards drier communities. Flooding could also affect these habitats, bringing in sediment and nutrients which could change species composition. Changing patterns of vegetation growth could also obscure historic field patterns, reducing the visibility in the landscape and affecting its historic character.

L. Rolling upland farmland

The grassland habitats of these upland pastoral areas are likely to experience changes in community composition as growing seasons become longer and there are fewer frost events, Conditions may become suitable for species currently associated with lower areas and they are likely to move upwards. If there is an expansion in lowland grass communities, there could be a move to increase agriculture, possibly leading to a greater sense of enclosure and human influence in these areas. Areas of woodland which provide a contrast with the grassland are likely to remain features in the landscape although the species composition of these areas may change.

M. Forestry and reservoir

This landscape character area is characterised by evidence of human use of the natural environment. Reservoirs are likely to be sensitive to changes in seasonal precipitation patterns with low water levels exposing the sides in summer and higher water in winter. These changes could affect the habitats provided by reservoirs and highly specialised plants which have adapted to live in draw-down zones could be vulnerable. Modern and historic structures associated with reservoirs could also be vulnerable to climate change, particularly drying out and cracking in summer and flooding in winter. However, given the current regime of regulation and monitoring, it is likely that the reservoirs and associated structures will be adapted and remain prominent features in this area.

Coniferous forest plantations may be vulnerable to drier conditions although as these are highly managed systems, it is likely that new species would be grown to adapt to changing climate conditions. A warmer, drier climate may encourage the use of faster growing, more drought tolerant tree species which could alter the appearance of the landscape. This area is likely to remain important for forestry and the managed feel of these areas will persist.

N. Farmed ridges

The farmed ridges support intensive beef and dairy farming due to the grassland habitats that are found there. Although grassland may be vulnerable to drying out in summer, it is likely that improved grassland will continue to be grazed intensively as other areas of the country become drier and more marginal for livestock farming.

B.3.2 Ecosystem services

Soil formation

Soils in the AONB are likely to be vulnerable to erosion and loss as a result of climate change, particularly peat soils which are sensitive to drying out. Soils support biodiversity and many of the ecosystem services delivered in the AONB, including agriculture, fresh water and climate regulation. The loss of soil could have significant implications for the mosaic of habitats found in the AONB as well as the benefits people derive from the landscape. However, the process of soil formation will persist. The rate of soil formation in the AONB may increase as rates of erosion, vegetation growth and decomposition increase due to warmer temperatures.

Food production

The grassland habitats of the AONB support livestock and dairy farming. Grassland habitats may be vulnerable to drought although the north west of England is projected to be less affected by low summer rainfall than the south and east. Warmer summers may increase the amount of bracken in the AONB and lead to higher fire risk, potentially reducing the area of grassland available for farming. Possibly more significant is the vulnerability of soils which underlay grassland areas and support the habitats required for dairy and livestock farming. However, these vulnerabilities are unlikely to result in a reduction of food production in the AONB. Climate pressures on other areas of the country and beyond may mean that food production in the north west of England increases.

Timber

A warmer, drier climate may encourage the use of faster growing, more drought tolerant tree species although there is likely to be some inertia given the legacy of existing stands of trees. Changes in planting could alter the appearance of the landscape but as an ecosystem service, timber production is likely to be relatively unaffected.

Energy

There is currently little energy produced in the AONB. There may be potential for energy production from biomass, particularly from woodlands and short rotation coppice, and hydro power. Whilst the species grown may alter as a result of climate change, the potential for energy to be produced from biomass is unlikely to be affected. Lower flows in watercourses during drier summers could reduce the potential for year-round hydro power.

Water resources and quality

Many aspects of the natural environment of the Forest of Bowland AONB contribute to the provision of freshwater including peat soil, wetland habitats, rivers and reservoirs. Peat soils and habitats also provide a water quality service as they filter impurities. However, peat soils and habitats are likely to be some of the most vulnerable assets in the AONB thus the role they play in improving water quality may be compromised.

Water resources are likely to be vulnerable to the impacts of climate change, particularly drier summers which may reduce water available in reservoirs and from surface water intakes. Drier summers could also affect peat soils and habitats such as bogs, fens and woodlands which store water, reducing the overall availability of freshwater in the area. The period of lowest supply is likely to coincide with the period of highest demand (from humans and the natural environment). This is likely to put pressure on water resources and new ways of storing winter rainfall for use in summer may be required.

Much of the infrastructure associated with water storage and transport in the AONB could be vulnerable to the impacts of climate change, for example, drying out and cracking of reservoir dams and spillways. The combined impacts of climate change on semi-natural and man-made assets means that the provision of freshwater is likely to be vulnerable to climate change.

Higher temperatures and lower rainfall in summer is likely to compromise water quality in rivers and waterbodies as water and oxygen levels are lower and pollutants are more concentrated and . Flooding can also be detrimental to water quality as sediment, nutrients and organic matter are washed in to watercourses.

Minerals

The underlying geology which provides minerals in the AONB is unlikely to be significantly affected by climate change although they may be subject to increased rates of weathering and erosion. Greater vegetation growth may increase the need for vegetation management at quarry sites.

Carbon storage

The peat soils and habitats of the AONB play an important role in storing carbon. Drier summers may lead to drying out of peat soils, making them more vulnerable to erosion. Peat soils may also be vulnerable to flooding and bog burst, resulting in further losses. The legacy of historic practices such as drainage, burning, grazing and peat cutting has reduced the ability of peat soils and habitats to withstand the impacts of climate change, increasing their vulnerability. Loss of peat soils would result in the release of carbon, contributing to the causes of climate change.

Flood alleviation

Wetter winters and a projected increase in extreme rainfall events are likely to increase the importance of the flood alleviation function provided by semi-natural habitats and floodplains in the AONB. As geomorphological features, floodplains are likely to be relatively in-sensitive to the impacts of climate change although streams may migrate. Semi-

natural habitats found on floodplains are likely to be more vulnerable. Wetland habitats are particularly significant in terms of their ability to store and slow flood waters. These habitats are vulnerable to seasonal cycles of wetting and drying; loss of habitat could reduce their ability to function as flood storage areas. Any loss in the overall area of semi-natural habitat in the AONB would have a negative effect on the flood alleviation function.

Pollination

The impacts of climate change on habitats which support large invertebrate populations will determine the vulnerability of the pollination service in the AONB. Invertebrates associated with upland hay meadows may be particularly vulnerable as montane species have a limited climate space which they can move to as temperatures warm. However, woodland, upland heath and waterbodies may not be as vulnerable. Whilst species composition may change, it is likely that the pollination function carried out by invertebrates will continue to be delivered.

Sense of place and inspiration

A sense of place will be specific to individuals but it is likely to be affected by a combination of landscape, biodiversity and ecosystem service assets and the relations between them. Large scale geomorphological features and landforms are likely to remain prominent in the landscape although the distribution of habitats and land uses which overlay them may alter. Historic environment assets often contribute to people's sense of place and the loss of historic features could change how people feel about the area. It is not possible to say how individuals will perceive potential changes in the natural environment although the impacts of climate change on the landscape could affect how people experience the AONB.

Tranquillity

Large expanses of semi-natural habitat with little evidence of man and the low density of settlement in the AONB provide a sense of tranquillity. Upland habitats, particularly blanket bog, are likely to be vulnerable to the impacts of climate change but are unlikely to lose their feeling of tranquillity as these areas are likely to remain marginal for farming and settlement. Increasing pressure for food production in lowland areas and the moorland fringe could result in an intensification of agriculture, potentially reducing the tranquillity of these areas. An increase in demand for recreation and higher visitor numbers could also reduce the feeling of tranquillity in the area. The network of country lanes and rights of way, settlements and attractions such as country houses and parks could become busier.

Recreation

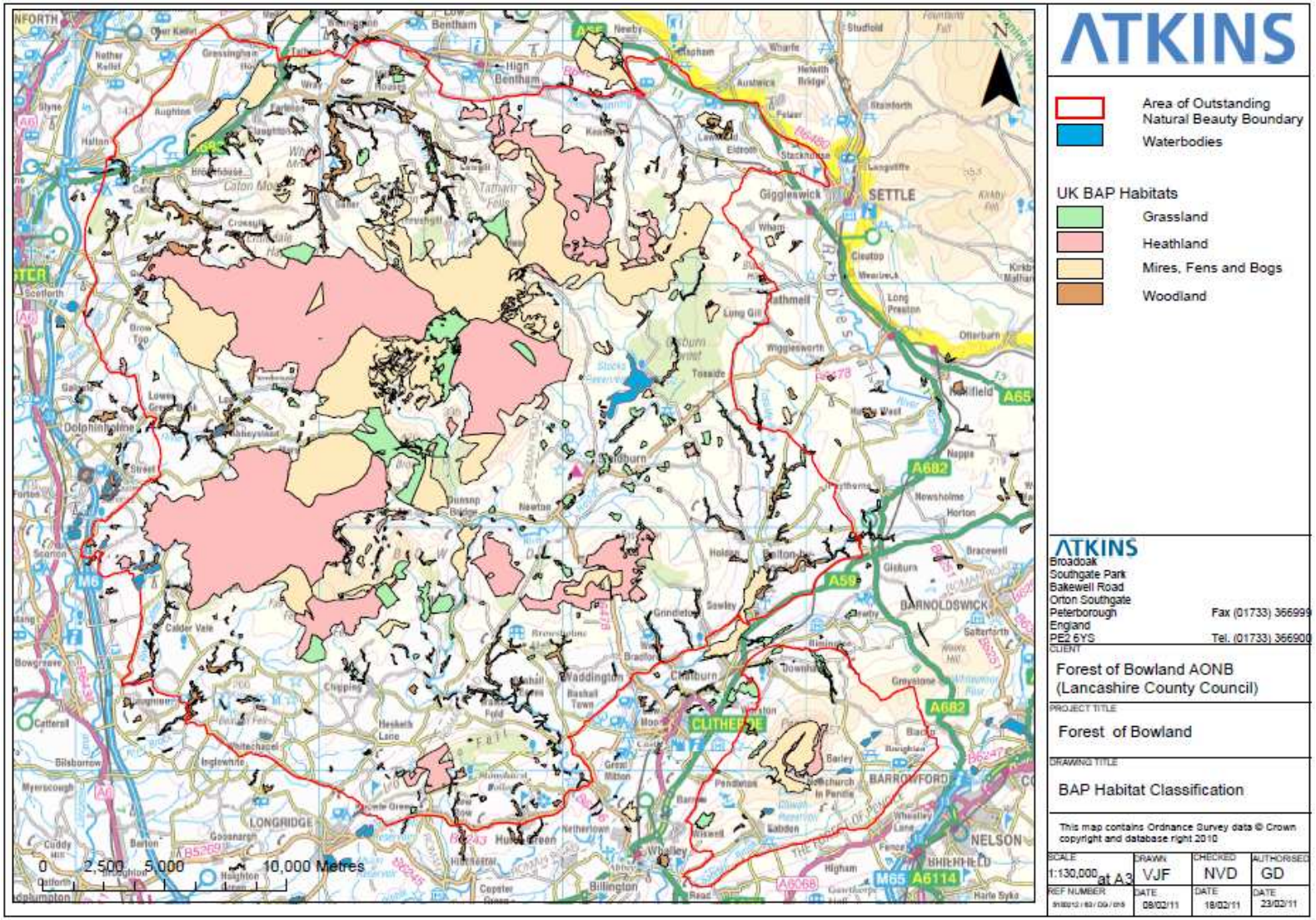
The natural environment of the AONB provides many opportunities for recreation. Warmer, drier summers could increase the demand for recreation in the area as people choose to spend more time outdoors and holiday in the UK. Warmer temperatures in spring and autumn may lengthen the season for recreation and tourism in the Forest of Bowland. Whilst individual recreation assets could be vulnerable to the impacts of climate change, for example, footpath surfaces and nature reserves designated for specific habitats or species, it is likely that the area will continue to offer a recreation service.

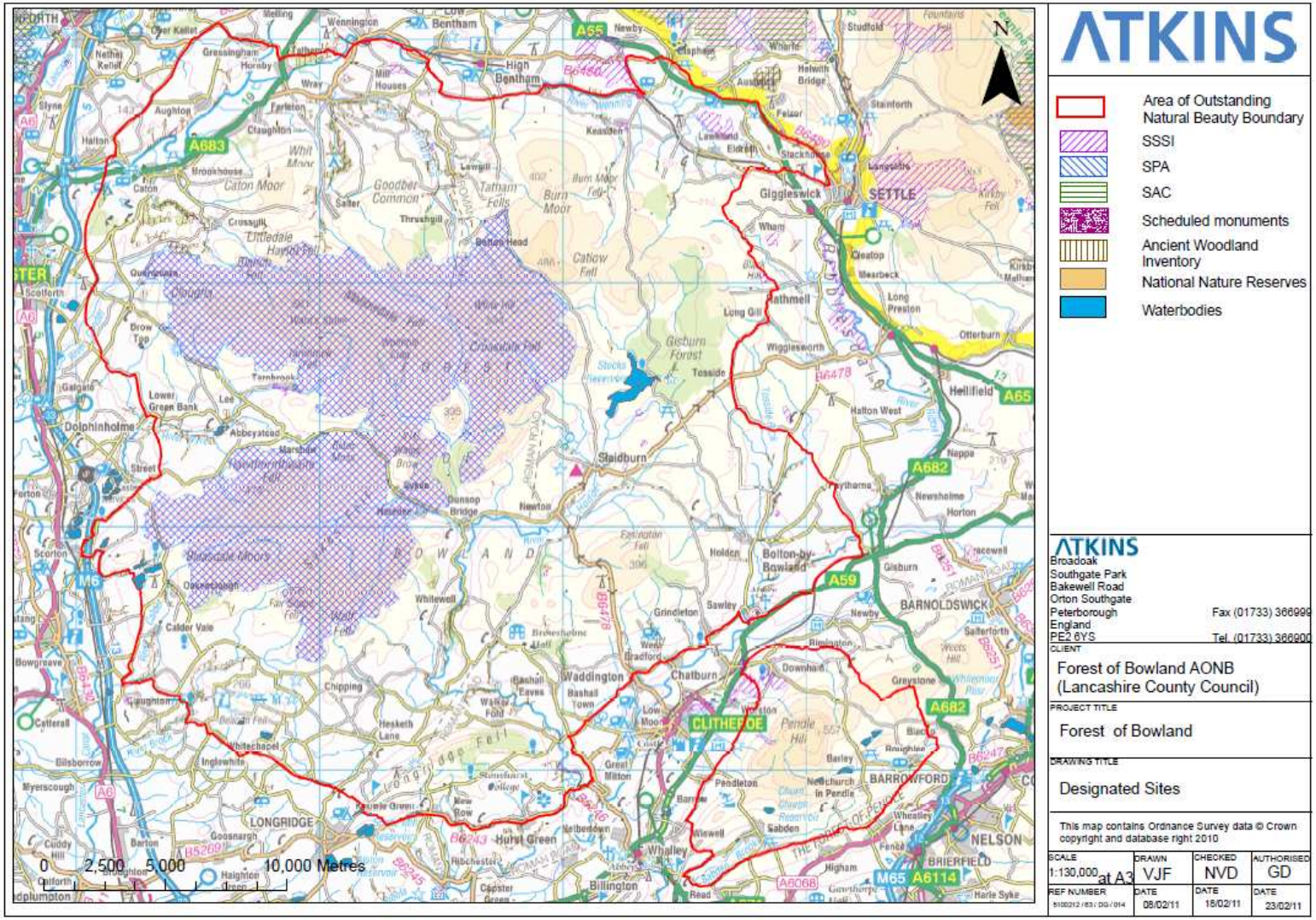
Knowledge

There are many assets which contribute to scientific and historic understanding of the area. Many of these are likely to be vulnerable to climate change, particularly buried archaeology in peat soils and historic buildings. Some areas designated for their scientific interest could be vulnerable to climate change including blanket bog habitats, upland hay meadows and the species they support. Once lost, the value of these assets in terms of knowledge may be lost if they have not be adequately surveyed and recorded.

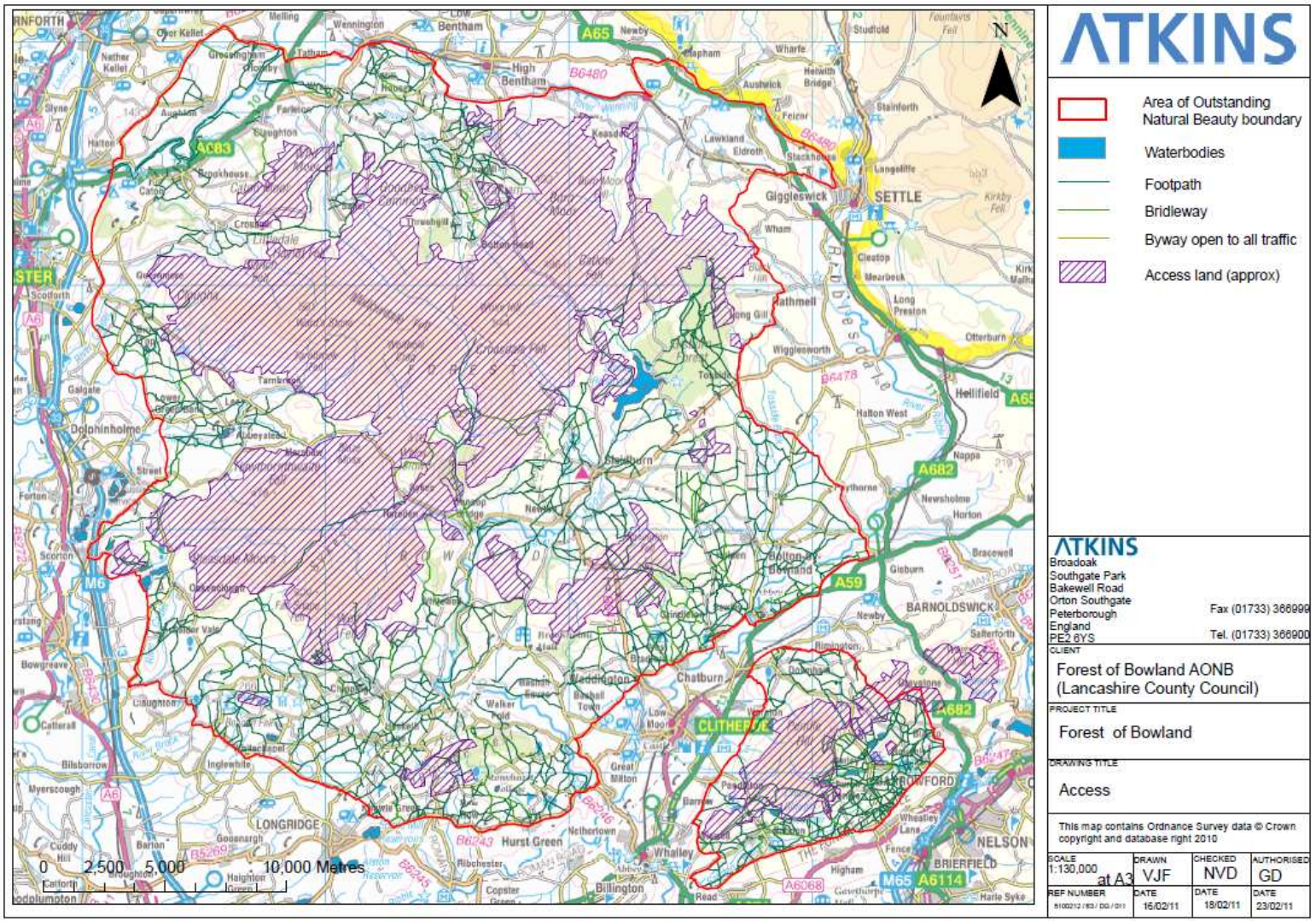
Appendix C: Maps of assets in the study area

C.1 BAP habitats




ATKINS
Area of Outstanding Natural Beauty Boundary
SSSI
SPA
SAC
Scheduled monuments
Ancient Woodland Inventory
National Nature Reserves
Waterbodies
N
0 2,500 5,000 10,000 Metres
ATKINS
Broadoak
Southgate Park
Bakewell Road
Orton Southgate
Peterborough
England
PE2 6YS
Fax (01733) 366999
Tel. (01733) 366900
CLIENT
Forest of Bowland AONB (Lancashire County Council)
PROJECT TITLE
Forest of Bowland
DRAWING TITLE
Designated Sites
This map contains Ordnance Survey data © Crown copyright and database right 2010
SCALE 1:130,000 at A3
DRAWN VJF
CHECKED NVD
AUTHORISED GD
REF NUMBER 5100212/ES/DG/014
DATE 08/02/11
DATE 15/02/11
DATE 23/02/11

C.3 Access and recreation



ATKINS

Area of Outstanding Natural Beauty boundary

Waterbodies

Footpath

Bridleway

Byway open to all traffic

Access land (approx)

ATKINS
Broadoak
Southgate Park
Bakewell Road
Orton Southgate
Peterborough
England
PE2 6YS
Fax (01733) 366999
Tel. (01733) 366900

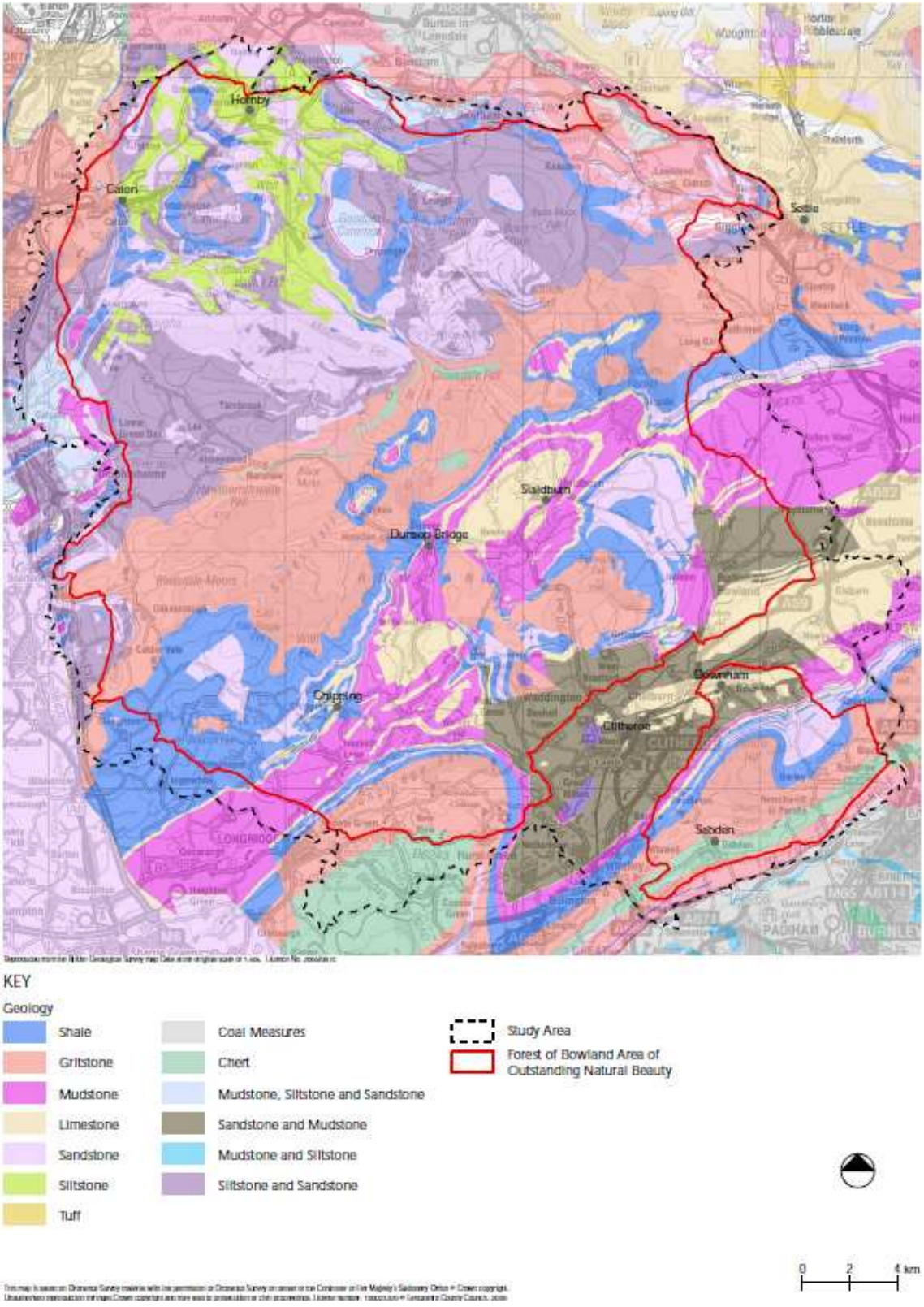
CLIENT
Forest of Bowland AONB (Lancashire County Council)

PROJECT TITLE
Forest of Bowland

DRAWING TITLE
Access

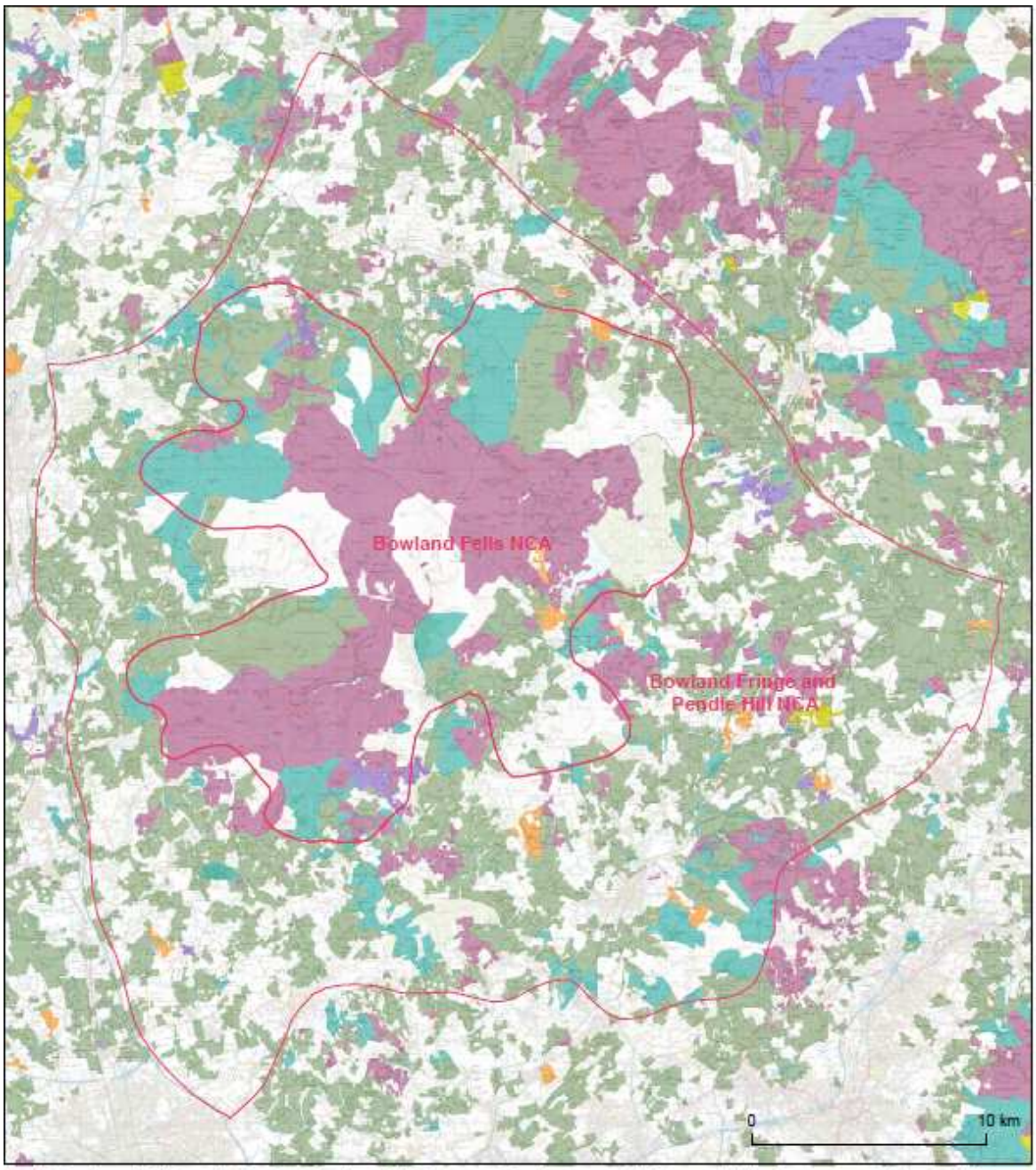
SCALE	DRAWN	CHECKED	AUTHORISED
1:130,000 at A3	VJF	NVD	GD
REF NUMBER	DATE	DATE	DATE
5100212/63/DG/011	16/02/11	18/02/11	23/02/11

C.4 Underlying solid geology of the Forest of Bowland



Map taken from Forest of Bowland AONB Landscape Character Assessment, Lancashire County Council 2009

C.5 Agri-environment agreements

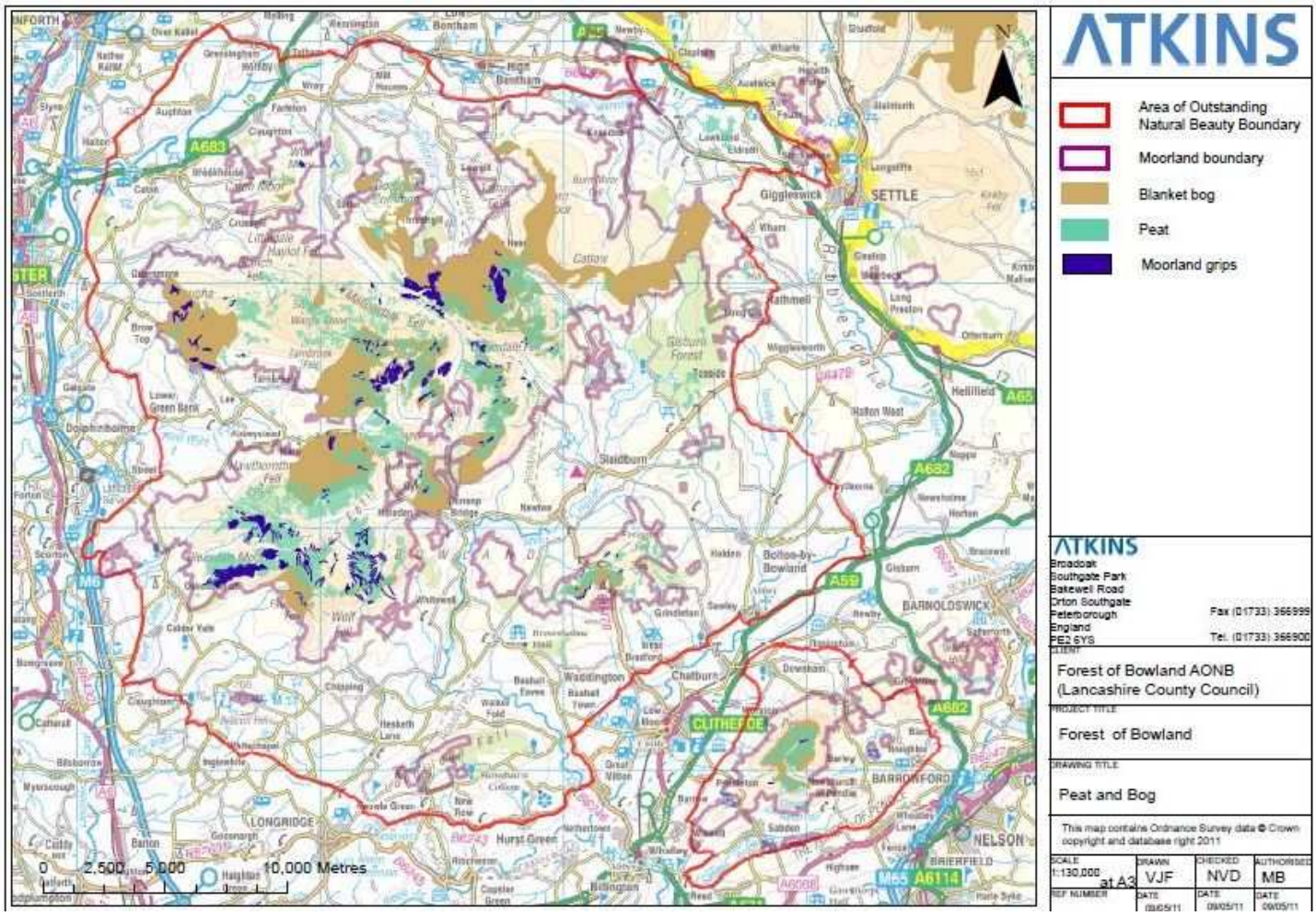


Bowland Fells and Bowland Fringe NCAs
Countryside Stewardship Scheme Agreements
Environmentally Sensitive Area Agreements

Environmental Stewardship Agreements (Jan 2011):
Entry Level Stewardship
Entry Level plus Higher Level Stewardship
Higher Level Stewardship
Organic Entry Level Stewardship
Organic Entry Level plus Higher Level Stewardship

NATURAL ENGLAND

C.6 The extent of blanket bog and peat soils in the Forest of Bowland AONB, including known drainage grips



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Revision	Purpose Description	Originated	Checked	Reviewed	Authorised	Date

FOREST OF BOWLAND
Area of Outstanding Natural Beauty

RIBBLE VALLEY
BOROUGH COUNCIL

NATURAL ENGLAND