

Responding to the impacts of climate change on the Morecambe Bay Limestones NCA

Prepared for Natural England
by
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July 2010



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1 Introduction

BACKGROUND

- I.1 During 2006 the key institutional stakeholders in the Northwest Region¹ developed '*Rising to the Challenge- A Climate change Action Plan for England's Northwest*' (NWCCAP). To deliver this, the Climate Change Partnership was established, which led to the inception of the North West Climate Change Unit in late 2007.
- I.2 Natural England, under Action 4.3, committed to: '***Undertake scoping studies to assess the potential impacts of climate change on the region's landscape, sensitive habitats and species and the contribution of natural systems to carbon sequestration and reduced flood risk.***'
- I.3 The purpose of the Character Area (CA) Climate Change Project is to identify the vulnerability of environmental assets and features in specific landscape areas of England to the effects of climate change and the appropriate adaptation responses for those areas. The results of the project will help develop landscape-scale adaptation strategies that will enable us to maintain the benefits we obtain from an ecosystem or landscape in the face of inevitable changes.

NATIONAL PROJECT

- I.4 Natural England is working to deliver a natural environment that is healthy now and in the future, enjoyed by people and used sustainably. However, the natural environment is changing, particularly as a consequence of land use change and climate change.
- I.5 While the reduction of greenhouse gases is essential to limit the extent of climate change, some impacts as a result of climate change are now unavoidable, due to the historical carbon dioxide emissions locked into our climate system. The natural environment is likely to be vulnerable to these impacts and it is therefore important to ensure that it has the capacity to adapt. Without such adaptive capacity, we put at risk our rich heritage of landscapes, ecosystems and wildlife. Natural England therefore needs to look ahead to secure the future of the natural environment. One way in which Natural England is achieving this is through the Character Area Climate Change Project, in which the implications of climate change on individual National Character Areas (NCAs) are examined.
- I.6 The purpose of the Character Area Climate Change Project is to identify the vulnerability of environmental assets and features in specific landscape areas of England to the affects of climate change and the appropriate adaptation responses for those areas. Using character areas enables this assessment to take a whole system approach and examine all the components which make up an individual landscape. The results of the project will help Natural England develop landscape-scale adaptation strategies that will enable us to maintain

¹ Including the Northwest Regional Development Agency; North West Regional Assembly; Government Office North West; Environment Agency (Northwest Region)

the benefits we obtain from an ecosystem or landscape in the face of inevitable changes.

- I.7 It is hoped that this report on the implications of climate change for the **Morecambe Bay Limestones NCA** and the proposed integrated strategic approach to adaptation will help inform future decisions for the area and ensure that proper account is taken of the impacts on the natural world as well as on communities and livelihoods. It is, however, neither Natural England's role nor intention to take such decisions, but to initiate debate on the impacts of climate change on the natural world so that well-informed decisions about its future can be taken.

APPROACH

A landscape approach – form and function

- I.8 The use of a National Character Area to define the study area enables landscape to provide an integrating framework to understand the potential impacts and responses to climate change. Using Character Areas as a unit of analysis provides a tool to help make sense of the complex, interactive nature of landscape – and of the effects of climate change. Landscape – to the extent that it exists as a physical entity – is a blend of natural and cultural elements and influences, informed by local history and geography. Landscape encompasses biodiversity, historical influences, cultural identity, enjoyment and economic value. It is the way these elements interact and the how they are perceived by society which defines a landscape's character and overall aesthetic value. Climatic influence, along with geology, soils, landform and biodiversity is a key defining variable of the physical character of landscape and as such the impacts of climate change are likely to be complex and subtle.
- I.9 Landscape exists as a form, but also a series of functions, reflecting that is a product of inter-related natural and cultural systems. The functions or utilitarian benefits provided by landscapes are termed **ecosystem services**. These can be subdivided into *goods* (e.g. food, fibre and clean water) and *services* (e.g. water purification, pollination and climate regulation) provided, free of charge, by the environment. The wealth of current and future generations is dependent upon its store of natural capital, largely in the form of ecosystems, capable of delivering essential goods and services. Maintaining and restoring healthy, natural ecosystems (as measured by their ability to sustainably deliver services and maintain their intrinsic value) is therefore critical to the economic, social and personal well-being of the society. However, human pressures have already significantly reduced the ability of many ecosystems to function and so deliver ecosystem services. In addition, increased frequency of extreme weather events and stress on ecosystems due to climate change may further decrease provision of ecosystem services unless appropriate action is taken.
- I.10 Protecting ecosystems in an abstract context is common sense, but the environment's ability to deliver critical services, like flood mitigation, soil formation, water purification, and climate regulation continues to be compromised through short-term decisions for economic or social reasons which fail to have regard to the wider impacts on the full range of ecosystem

services. Often this is because the functionality of a particularly area of land is poorly understood, with local authority planning documents identifying brownfield land for development without recognising the role that land is currently performing (for example in flood mitigation), as well as broader biodiversity and local aesthetic values. Integrating vulnerability and functionality into assessments of the impact of development will help balance the competing demands that society currently places on the natural environment and help inform the development of appropriate sustainable responses to climate change.

Methodology

- I.11 This study has been produced using the methodology devised for Natural England to guide Phase 2 of the NCA Climate Change Project². Based around a consultative approach, drawing on the expertise of local and regional experts and stakeholders, the study followed the broad process illustrated in **Figure I.1**.
- I.12 Stakeholders identified the key valued assets of the Character Area, under the broad themes of:
 - biodiversity;
 - geodiversity;
 - access and recreation;
 - the historic environment;
 - landscape; and
 - ecosystem services.
- I.13 An assessment of the likely impacts of climate change was then conducted, highlighting the vulnerabilities of each asset, and drawing out appropriate adaptive responses to these challenges. Each thematic response was then 'screened' against the assets identified under the other five themes to identify potential conflicts, synergies and opportunities for action.
- I.14 The findings of this exercise are drawn together in **Section 2** below and the proposed adaptive responses are presented in **Section 3**.

² Atkins 2009 *Natural England Character Area Climate Change Project: Phase 2 Guidance* unpublished

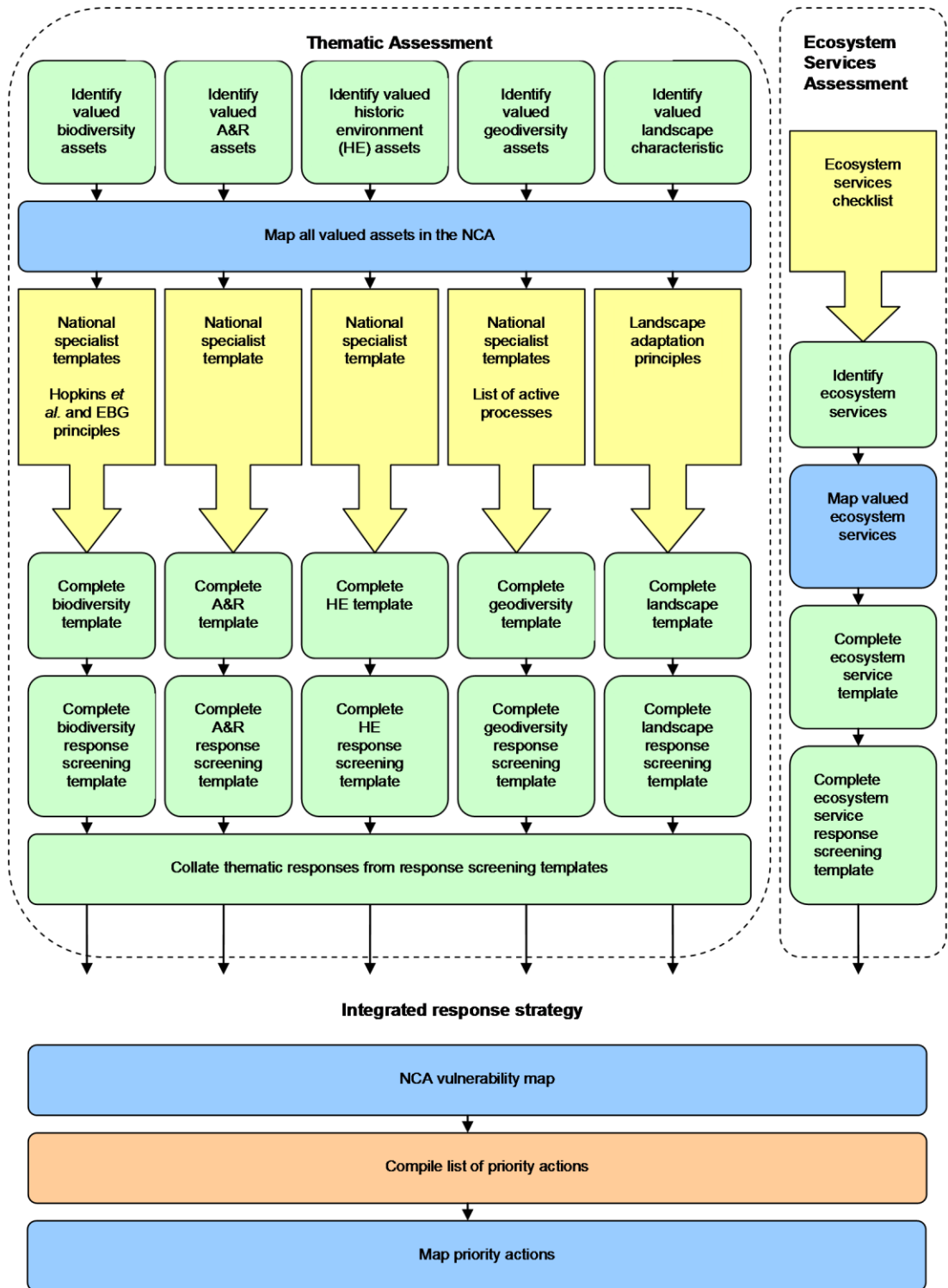


Figure I.1: Process used in developing action plan

Vulnerability assessment

- I.15 In assessing the vulnerability of key environmental assets, a series of templates for each asset theme (biodiversity, geodiversity, access and recreation, the historic environment, landscape and ecosystem services) have been devised to capture individual assets and assess their likely vulnerability to key climate-driven variables. These templates include direct and indirect impacts, as well as proposed response to enhance the adaptive capacity of the asset. Indirect impacts are recorded to capture socio-economic factors such as a community's response to increased flooding or changes in agricultural patterns, which may have more detrimental effects on habitats than the direct biophysical impacts of climatic changes.

Developing adaptive capacity

- I.16 The concept of adaptive capacity as defined in Hopkins *et al.* (2007) and the England Biodiversity Strategy (Defra 2008), stresses the fact that the aim of adaptation is to maintain the value or function of the landscape or ecosystem, rather than necessarily attempting to prevent change. Adaptive management involves making incremental changes to management practices to enable effective planning for, and coping with, uncertainty. The approach involves making changes to an existing management practice and monitoring the results to ensure the response is effective. As a result of ongoing monitoring, the management practice/strategy may need to be reviewed again. A good example of adaptive management is having the flexibility to alter the timing of grazing and stocking levels each year based on experience of the previous year.
- I.17 In developing an approach to enhancing the adaptive capacity of the Morecambe Bay Limestones National Character Areas opportunities for win-win and low regrets adaptation responses have been sought as the first steps in an adaptive management process.

Table I.1: Responses to climate change

Type of Response	Definition
'Win-win'	Is beneficial (in terms of reducing vulnerability to climate change) to more than one asset / characteristic of the natural environment.
Low regrets	Is beneficial to the natural environment regardless of whether the projected climate change impact occurs. Adapting to climate change includes doing things that Natural England does already but to a greater extent

2 Impacts of climate change on the Morecambe Bay Limestones NCA

INTRODUCTION

The Morecambe Bay Limestones NCA

- 2.2 Situated on England's windswept west coast, the character area comprises the coastal and inland area lying to the south and west of the South Cumbria Low Fells and enclosing the northern and eastern margins of Morecambe Bay. From the coastal pastures and woodlands of Baycliff and Bardsea to the south of Ulverston, the area includes: Cartmel Sands and the Crake/Leven Estuary; the Cartmel peninsula; the town of Grange over Sands; the Whitbarrow limestone scarp; the Lyth Valley; the Kent Estuary; and the whole of the Arnside and Silverdale Area of Outstanding Natural Beauty (AONB). On the eastern boundary, the higher hills formed by Hutton Roof and Farleton Knott separate the area from the Lune Valley, the Yorkshire Dales and the South Cumbria Low Fells. (See **Figure 2.1** below)
- 2.3 The character of the area is largely defined by the interaction between the strong maritime influences of the coastal saltmarshes, broad expanses of intertidal flats and the sweeping, constantly shifting, vistas across the waters of Morecambe Bay. The inland landscape is one of contrasts: between species-rich grasslands, semi-natural woodlands, mosses and fen reedbeds, and limestone outcrops and gently undulating drumlin landscapes.
- 2.4 The key qualities of the area, as defined by the National Character Area study, are:
- Wide expanses of shifting intertidal sandflats and saltmarsh, gravelly or muddy beaches, and backed by low limestone cliffs.
 - Low undulating farmland of pastures divided by drystone walls, with infrequent individual windswept trees, but with areas of scrub and broadleaved woodland.
 - Conspicuous limestone hills, with cliffs and scree slopes, rising above the low-lying pastures and wetlands.
 - A richness of semi-natural habitats, including limestone pavements, scrub, semi-natural coppice woodland, herb-rich grasslands, peaty fenlands and mosslands.
 - Inland, scrub woodland including juniper, and unimproved grasslands on gently undulating hills, divided by shallow valleys with hedgerows and damson orchards.
 - Stately homes set in parkland landscapes with well maintained gardens.



Figure 2.1: National Character Area Map

UKCP09 CLIMATE PROJECTIONS

Context of UKCP09

- 2.5 UKCP09 is the fifth generation of climate change information for the UK, and is the most comprehensive package produced to date. Unlike previous suites of UK climate prediction models, UKCP09 provides probabilistic projections of climate change based on known sources of uncertainty. Over land, UKCP09 gives projections of changes for a number of climate variables, averaged over seven overlapping thirty year time periods, at 25 km² resolution and for administrative regions and river basins. Similar projections are given for a smaller number of variables averaged over marine regions around the UK.

- 2.6 The probabilities given in UKCP09 represent the relative degree to which each climate outcome is supported by the evidence currently available, taking into account current understanding of climate science and observations, and based on expert judgement. UKCP09 gives projections for each of three of the IPCC's Special Report on Emissions Scenarios (SRES) scenarios (broadly – 'high, medium and low'³) to show how different emissions pathways affect future climate. Each of the emissions scenarios suggests a different pathway of economic and social change over the course of the 21st Century, not accounting for planned mitigation measures.

Headline impacts

UK-wide

- 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. In addition, the incidence and severity of extreme weather events will increase.
- Sea levels rise, and are greater in the south of the UK than the north due to the effects of isostatic rebound in the north, and downwarping/subsidence in the south.

Impacts on the North West of England

- The central estimate of increase in **winter mean temperature** is 2.6°C; it is very unlikely to be less than 1.4°C and is very unlikely to be more than 4.1°C.
- The central estimate of increase in **summer mean temperature** is 3.7°C; it is very unlikely to be less than 0.6°C and is very unlikely to be more than 5.8°C. The central estimate of change in winter mean precipitation is 16%; it is very unlikely to be less than 3% and is very unlikely to be more than 35%.
- The central estimate of change in **summer mean precipitation** is -1%; it is very unlikely to be less than -42% and is very unlikely to be more than 0% (i.e. to increase).

VULNERABILITY OF NATURAL ASSETS TO THE IMPACTS OF CLIMATE CHANGE

Introduction

- 2.7 Based on the asset mapping process, a series of themed templates have been produced which assess the direct and indirect impacts of climate change on the natural environment and ecosystem services of the Morecambe Bay Limestones NCA, together with proposed responses.

³ (AIFI (called High in UKCP09), AIB (Medium) and BI (Low)) – IPCC

Impacts on biodiversity

2.8 A simplified vulnerability index has been used to provide an indicator of potential vulnerability of key assets:

	Impact on an asset which will significantly change the character or nature of the asset, or destroy the asset.
	An asset which will require careful management and monitoring to support its adaptive capacity.
	An asset which is likely to be more resilient to climate change impacts or for which climate change impacts may be beneficial.

Table 2.1: Summary of impacts on biodiversity

Habitat type	Priority habitat	Vulnerability
Woodland	Wood pasture and parkland	Low
	Wet woodland	Medium/ Low
	Limestone mixed ash	Low
	Mixed oak and ash	Low
	Lowland mixed deciduous and coppice woodland	Low
	Ancient and semi-natural woodland	Medium
	Yew woodland	Medium
Grassland, orchards and hedgerows	Species-rich hedgerows	Low
	Traditional orchards	Medium
	Calcareous grassland	Low
	Lowland acid grassland	Low
	Lowland meadows, unclassified species-rich and semi-improved pasture suitable for restoration	Medium
	Lowland wet grassland and lowland drained farmland, suitable for re-wetting	Medium/ high
Heathland and limestone pavement features	Coastal limestone heath and cliff-top grassland	High
	Limestone pavement flora	Medium
	Flora associated with underground karst features	Low
Coastal	Saltmarsh	High
	Estuaries and intertidal flats	Low
	Shingle banks and beaches	Medium
	Coastal slope and clifftop	High
	Saline and brackish lagoons	High
	Rock outcrops and rockpools	Medium
Wetlands	Drainage ditch systems	Medium
	Lowland raised bog	Medium/ High

Habitat type	Priority habitat	Vulnerability
	Reedbed	Medium
	Shallow lakes / open water mosaics	Medium
	Fens	Medium
	Coastal and floodplain grazing marsh	Medium

<http://www.defra.gov.uk/wildlife-countryside/resprog/findings/ebs-climate-change.pdf>

Woodland habitats

2.9 All woodland types are likely to be affected by summer droughts when the trees are in full leaf and transpiration losses are high. Woodlands on well-drained, south facing slopes are likely to be affected most severely, while those in more sheltered valley locations may be more robust. In addition to their intrinsic value, networks of woodland habitat are key mechanisms to facilitate species' adaptation to the effects of climate change.

2.10 Key impacts are likely to include:

- Increased stress on trees:
 - Increased soil moisture deficit
 - Increased vulnerability to pests and disease
 - Increased incidence of death from drought
- Increased fire risk
- Risk from incoming pests and diseases to which native trees have little resistance
- Change in species mix in existing woodlands
- Potential losses of symbiotic species
- Increased losses to windthrow:
 - Damage to other interests from falling trees / branches
- Invasion of existing woodlands by other tree species:
 - E.g. beech invading oak woodlands
 - Changes in canopy density/competitiveness – potentially affecting shrub understorey
- Changes in ground flora composition:
 - Competition with saplings
- Changes in water table:
 - Winter rises may 'drown' roots of floodplain woodland
 - Rising sea levels creating the potential for salination of groundwater
- Likely changes to regeneration patterns / lifecycles:
 - Changes in seed production and fecundity

- Lack of winter frosts potentially affecting bud production and seed germination
- Changes in agricultural and land management practices potentially impacting on soil biodiversity and farmland invertebrates, birds and mammals

Grassland, orchards and hedgerows

2.11 The majority of grassland habitats are vulnerable to increased drought resulting from warmer, drier summers. Similarly, lack of winter frosts may enable pest and diseases to propagate where they may previously have been killed off by low temperatures.

2.12 Key impacts on grasslands are likely to include:

- Shallow-rooted species likely to suffer most from summer drought
- Increased risk of wildfires resulting in damage to lower plant assemblages
- Potential for delayed succession as a result of the longer growing season
- Decline in abundance of specialist mosses, fungi and associated invertebrate communities
- Drought conditions favour annual over perennial species, potentially resulting in loss of/change in species diversity
- Expansion of southern English grassland species
- Stress-tolerant species and ruderals likely to spread
- Significant changes to phenology:
 - Earlier flowering/setting seed
- Changes to agricultural patterns may increase pressure on unimproved grassland for arable production
- Changes to summer grazing patterns as a result of water availability for livestock

2.13 Traditional orchards are an important aspect of the NCA's character, and provide a range of habitat and feeding opportunities for native species. Key impacts are likely to include:

- Increased growth per year of woody species
- Increased prevalence of pests and disease
 - Northward expansion of thermophile invertebrates
 - Likely spread of mistletoe adding to stress on orchard trees
- Increased diversity of viable fruit species
- Increase scrub growth in under-managed orchards
- Potential reduction in crops from traditional fruit varieties:

- Fewer frost events affecting chill requirements for bud development
 - Increased soil moisture deficit:
 - Reduced crop and individual fruit size
 - Potential for waterlogging as a result of wetter winters
 - Increased windthrow of orchard trees:
 - Risks exacerbated by locally thin soils
- 2.14 Species-rich hedgerows provide important habitat corridors through farmland areas, creating opportunities for migration in response to climate change. They can also play a valuable role in reducing soil erosion, providing shelter from strong winds for newly-ploughed fields.
- 2.15 Key impacts are likely to include:
- Increased mortality/dieback of hedgerow trees
 - Increase susceptibility to pests and diseases
 - Potential loss of connectivity of wet ditches and hedgerow networks
 - Increased siltation of wet ditches as a result of increased runoff during wetter winters
 - Wind damage
 - Longer growing season
 - Decline of drought intolerant hedgerow species

Heathland and limestone pavement features

- 2.16 Limestone upland landscapes are a fundamental aspect of the area's character. They support a unique and sensitive range of species and habitats which are particularly sensitive to changes in climate – notably levels of precipitation and potential effects on geochemistry.
- 2.17 Key impacts are likely to include:
- Possible increases in biomass due to longer growing season:
 - Invading species out-competing existing assemblages
 - Changes in community composition
 - Potential for increased erosion during winter episodes of intense rainfall:
 - Washing away thin gryke soils and causing physical damage to plants
 - Changes in chemistry of precipitation likely to result in an increase in chemical weathering of limestone pavement on the surface and affect troglodytic plants and lichens
 - Warmer winters will reduce the incidence of frost damage

- Increased risk of wildfires, damaging limestone pavement and floral communities
- Increased risk from pest species (e.g. heather beetle)
- Reduction in bare ground habitats
- Decreased flowering of heather species, and overall decrease in productivity:
 - Stress increasing vulnerability to pathogens

Coastal habitats

2.18 The sweeping expanses of Morecambe Bay's intertidal flats and saltmarshes are the key components of the NCA's coastal environment. Projected sea level rise over the coming century, coupled with increased prevalence of storm events, is likely to significantly reshape the coastline.

2.19 Key impacts are likely to include:

- Increased tidal flooding of saltmarsh and higher storm surge heights:
 - Where no constraints exist, marsh may migrate inland
 - Acceleration of erosion of seaward edge of marshes
 - Potential for 'squeeze' between seaward extent of marsh and hard coastal defences/natural barriers – resulting in net loss of habitat
 - Reduction in effectiveness of saltmarsh in buffering the effects of storm events on inland resources
 - Increased sedimentation and barrier breaches could result in the loss of saline lagoons
 - Hotter summers could result in oxidisation of sediments and organic matter, triggering release of CH₄ and CO₂
- Changes in fluvial and estuarine processes (result of changing rainfall patterns and intensity):
 - altering availability of sediment for marsh accretion:
 - loss of base level of estuarine food webs – increased energy in river flows flushing finer organic particles further out to sea (resulting in a sandier substrate)
 - increased flows along river channels during wetter winters – and much-reduced flows during drier summers – changing nutrient inputs to Morecambe Bay (more defined 'pulsing' of nutrients)
- Increased dynamism in estuary channels and sand/gravel beach systems
- Increased cliff erosion and increased incidence of landslides
- Changes in water table potentially affecting integrity of lagoons

- Need to protect human assets and infrastructure creating potentially major conflicts with natural processes:
 - Managed realignment may result in habitat change / loss
 - Need for hard coastal defences can result in coastal squeeze
 - Potential for estuarine renewables (e.g. tidal barrage or tidal lagoons) have the potential to affect natural processes

Wetlands

2.20 Changes in precipitation levels and temperatures are likely to have a significant effect on the mires, fens and other wetlands of the Character Area.

2.21 Key impact are likely to include:

- Rising sea-levels:
 - Direct inundation of coastal wetlands
 - Salination of groundwater-fed fen, where net reductions in groundwater flows enables permeation by salt water:
- Low flows in streams and drainage ditches increasing nutrient levels due to increased retention times
- Periods of low water level reducing available fish spawning habitat (e.g. accessible marginal vegetation)
- Increased nutrient levels, evapo-transpiration and primary productivity reducing dissolved oxygen levels
 - Greater frequency and duration of algal blooms
 - Increased potential for invasive species
- Increased runoff, erosion, sediment-loading and nutrient delivery as a result of high intensity winter rainfall:
 - Potential loss of submerged plant communities
 - Potential damage to shellfish beds
 - 'forward switch' to turbid algae-dominated state in water bodies
- Hotter, drier summers resulting in seasonal drying of fens:
 - Loss of species
 - Significant carbon release, followed by nutrient release on re-wetting
- Increased winter rainfall (and increased intensity):
 - Unpredictable inundation/erosion of floodplain fen
 - Damage to floodplain assets
 - Siltation of inundated assets (potential for pollution or change in nutrient levels, chemistry etc)

Impacts on geodiversity

- 2.22 Areas of limestone karst geology, such as those within the Arnside and Silverdale AONB, are a nationally significant resource. In addition to their geological interest, they support unique floral communities - including a number of UKBAP habitats. Natural formations and man-made stratigraphic exposures are susceptible to a range of climate change impacts.
- 2.23 The relics of the Quaternary glaciations to which the NCA was subject also contribute significant geological interest. Deposits of glacial till floor most of the valley between the limestone outcrops, while extensive drumlin fields create the rolling topography of the inland portion of the area. Similarly, post-glacial sea level fluctuations carved out a number of beach features

Direct impacts

- 2.24 Impacts are likely to include:
- Increased vegetation growth on exposures, obscuring features of interest
 - Increasingly intense cycles of wetting and drying producing more pronounced slumping and collapse of exposures
 - Increased storminess and rising sea levels resulting in the rapid erosion of softer areas of Morecambe Bay's coastline:
 - Damage to coastal limestone cliffs and associated fossil assemblages
 - Increased winter rainfall and more intense flooding events:
 - Increased risk of collapse in karst caves
 - Washing in of pollutants and debris
 - Change in water chemistry increasing chemical weathering
 - Increased storm events and sea level rise damaging impounded lagoons:
 - Siltation from direct marine inundation or from runoff
 - Increased erosion from wave action
 - Potential for salination of aquifers if inland water table falls (e.g. if there is a net reduction in rainfall or summer abstraction increases significantly)
 - Climate change is likely to alter ongoing natural geomorphological processes within Morecambe Bay:
 - Increased river energy in winter changing rate/distance/patterns of sediment deposition
 - Increased scour along watercourses / increased runoff – changing nutrient deposition in the Bay
 - Changing locations of saltmarsh – eroding at existing locations, accreting elsewhere

- Potential depletion of gravel beaches (post-glacial features, not currently accreting)
- Potential for eutrophication of marl lakes (e.g. Hawes Water) from increased runoff and higher water temperatures

Impact of other responses to climate change

- Works required to stabilise cliffs where they are a threat to infrastructure or human life:
 - Could damage / reduce visibility of or access to important exposures
- Development of tidal stream, barrage or lagoon-type electricity generating stations could have a significant effect on the natural processes of Morecambe Bay
- Installation of hard coastal defences is also likely to have an effect on sediment dynamics, potentially affecting the accretion/erosion of saltmarsh, intertidal flats and beach deposits
- Changes in patterns and intensity of moorland management (e.g. muirburn) could affect geological exposures

Impacts on access and recreation

2.25 The Arnside and Silverdale AONB is a regionally important resource for tourism and outdoor recreation. Its high quality landscapes and natural environments are a critical part of its enduring appeal to visitors.

Direct impacts

2.26 The effects of climate change on these special qualities clearly have the potential to affect its level of attractiveness. Equally, changing weather patterns may increase the area's appeal over other destinations.

2.27 Impacts are likely to include:

- Increased summer visitor numbers due to warmer temperatures and reduced rainfall:
 - Unpleasantly hot conditions further south may increase visitor pressure
 - More scope for visitors to make use of beaches
 - Potential for erosion
 - Increased pressure on access network and visitor resources
 - Increased demand for water-based activities in the Bay at high water
 - Increased pressure on road network and popular locations (limits of available parking and public transport connectivity)
- Increased intensity of severe weather events potentially damaging access infrastructure (e.g. flooding/erosion)

- Increased vulnerability to wildfires
- Increased use of woodland paths etc. for recreation due to availability of shade:
 - Increased hazard from falling branches ('sudden limb drop')
- Potential health and nuisance impacts of increased invertebrate populations – reduced mortality due to milder conditions and increased potential of zoonotic infection
 - Ticks
 - Mosquitoes and other biting insects particularly in wetland areas

Impact of other responses to climate change

- 2.28 The development of coastal defences, or adoption of a managed realignment approach to rising sea levels, is likely to have an impact on access to valued sections of coastline. Similarly, fluvial flood management practices have the potential to affect access along riversides, since hard defences are likely to significantly change the character of the area and floodplain restoration is likely to result in periodic inundation.
- 2.29 Developing adaptive capacity for biodiversity – providing 'climate space' into which species and habitats can migrate – is likely to create new opportunities for access to and appreciation of natural heritage.

Impacts on the historic environment

- 2.30 The Character Area has a particularly rich cultural heritage, spanning from the Mesolithic to the industrial age. Despite surviving for generations, archaeological remains, historic buildings and landscapes are vulnerable to the direct impacts of climate change and mitigation and adaptation measures required to protect other interests.

Direct impacts

- 2.31 Climate change is likely to result in the following impacts:
- Changes in soil moisture levels:
 - Drying and damaging buried deposits – particularly significant for well-preserved wetland sites
 - Loss of stratigraphic integrity through heaving/cracking
 - Increased potential for wind erosion in drier soils and from intense storm events
 - Potential for changes in soil pH increasing speed/changing patterns of decay
 - Marine or fluvial flooding/inundation:
 - Total loss of sites
 - Erosion

- Change in soil chemistry – precipitation/solution of salts may damage remains
- Changes to agricultural practices:
 - Potential for intensification in response to longer growing season and reduced agricultural potential in more southerly areas – increasing plough attrition on buried archaeology
 - Intensification/switch to arable increasing pressure to amalgamate fields and destroy historic field patterns and boundaries and ancient, species-rich, hedgerows
 - Changes to deeper-rooting crops in response to moisture deficit, or for energy crops (*miscanthus*, short-rotation coppice)
- Increasing intensity of weather events:
 - Wind damage to historic properties and historic plantings in designed landscapes (and wider impacts on historic landscapes)
 - Intense rainfall overwhelming rainwater goods/thatched roofs
 - Flood damage to historic buildings and contents
 - Issues with intrusive damp – warmer conditions also making some mould and fungi species more vigorous
 - Moisture driven further into stonework and joints
- Cycles of intense wetting and drying damaging stonework through:
 - Physical and chemical erosion – limestone buildings particularly susceptible (especially as pH of rainfall decreases with increasing atmospheric CO₂ concentrations)
 - Precipitation of salts, causing spalling and other damage to historic buildings
 - Increased growth of some vegetation affecting buildings (climbers, fungi, some lichens)

Impact of other responses to climate change

2.32 Depending on response strategies, likely impacts include:

- Floodplain restoration / upper catchment flood attenuation likely to periodically inundate sites in affected areas:
 - Planting of floodplain woodland or other habitat change could damage buried archaeology
 - Damage to riverside buildings (e.g. historic mills etc.)
- Managed realignment to address rising sea levels:
 - Could potentially result in the inundation and total loss of sites and monuments in the littoral zone

- Likely that sites in the intertidal zone will be lost as erosive power of river/channel systems increase and patterns of sediment erosion/accretion change
- Development of tidal-powered renewables potentially altering patterns of sediment transport – burying some sites, exposing/eroding others
- Responses designed to boost habitat connectivity, provide habitat succession or re-create lost assets have the potential to impact on cultural heritage
- Increased intensity of moorland management (i.e. muirburn) could result increased potential for damage to archaeological sites and monuments

Impacts on landscape

2.33 Landscapes, as products of the interaction of a range of natural processes, cultural factors and valued assets, are particularly vulnerable to the effects of climate change. Impacts of vegetation patterns, coastal processes and sea levels, river behaviour and – critically – human responses to change all have significant potential to alter the special qualities of landscapes.

Direct impacts

2.34 Key changes to landscape character, grouped by broad theme, are likely to include:

- Coastal landscapes:
 - Significant changes to intertidal flats as sediment and river channel dynamics evolve
 - Squeeze/loss of extensive areas of saltmarsh in current locations – sediment accretion and development of new marshes in other areas
 - Increased attrition of sand and gravel beaches– potential for inland roll-back
- Agricultural landscapes:
 - Dieback of hedgerows, shelter belts and field trees
 - Drying of wet ditch systems and change in character of wet grazing areas
- Woodland:
 - Gradual change in dominant species
 - Expansion of natural regeneration into open upland and wetland margin areas
 - Continuing change in flushing and leaf drop dates
 - Stress and death of veteran trees and ancient woodlands – reduced recruitment of native species

- Upland landscapes:
 - Colonisation of limestone pavements by tree species
 - Movement of treeline and influx of scrub and succession vegetation
 - Changes in vigour of heather moorland
 - Increased prevalence of wildfires

Impact of other responses to climate change

- Coastal landscapes:
 - ‘Hold the line’ approach to coastal defence will reduce natural feel to coastline as deposits erode up to limits of defences
 - Insertion of new hard defences will change the character of settlements
 - Managed realignment, where applied, will establish new shorelines and intertidal habitats – significantly changing coastline and resulting in loss of existing landscape assets in affected areas
- Agricultural landscapes:
 - Potential for intensification:
 - Possible move from pastoral to arable farming
 - Introduction of new crop varieties with possible impacts on landscape character
 - Pressure to amalgamate fields to accommodate larger, more efficient machines – eroding historic character through loss of hedgerows, boundary walls, field banks and ditches; attrition of surviving areas of ridge and furrow
 - Cessation of pumping in artificially drained areas (e.g. Lyth Valley):
 - Re-wetting and habitat creation completely changing the character of a strongly agricultural area
 - Development of habitat networks
 - Potential to make a positive contribution to landscape character
- Woodland:
 - Potential changes in species and provenance of conifer crops
 - Changes in areas suitable for afforestation – potential for increase in afforested area for carbon sequestration, biomass and increased demand for indigenous timber products
 - Increased management of broadleaved woodlands for coppice (for biomass)

Impacts on ecosystem services

- 2.35 The effective functioning of natural processes within the NCA provides human society with a suite of indispensable services, ranging from food production and climate regulation to flood protection and water purification. To provide man-made equivalents would be cripplingly expensive and virtually impossible, therefore the protection and enhancement of ecosystem services must be a fundamental aspect of any strategy to adapt to the effects of climate change.
- 2.36 As noted above, the environment offers mechanisms which will aid adaptation to climate change – most notably in relation to water management – but they may also be compromised or altered by climate impacts.

Direct impacts

- 2.37 Impacts are divided by category of ecosystem service:
- **Supporting services:**
 - Biodiversity – see above for a more comprehensive account of impacts.
 - **Provisioning services:**
 - Fruit production in traditional orchards may be affected by lack of winter frosts to trigger bud initiation
 - Longer growing season may have a positive impact, but could reduce the viability of traditional fruit varieties
 - Waterlogging and flooding of soils in winter likely to affect food production
 - Longer growing season and hotter, drier summers affecting range of crops that can be grown
 - Potentially triggering switch from pastoral to arable agriculture in places
 - Increased frequency and severity of storm events likely to damage crops and result in windthrow of orchard trees
 - Changes in sea level and sediment dynamics in the Bay are likely to have an effect on shellfish productivity
 - Rising sea levels could potentially affect the viability of marine renewables in the area
 - **Regulating services:**
 - Sea level rise and increased storminess may result in depletion of existing saltmarsh and intertidal flats, reducing ability to buffer coastline from wave action and triggering substantial carbon release from disturbed and decaying sediment/organic matter

- Summer drying of peat soils will trigger decay and carbon release, damaging mosses potential as carbon stores
- Increase in storm damage to woodlands will affect their role as carbon stores; their viability for near carbon neutral fuel use; role in air quality improvement and effectiveness as shelter and shade
- Potential for floodplain woodland to attenuate effects of floodwater
- **Cultural services:**
 - Changes in sediment dynamics could change the character of Morecambe Bay, potentially affecting sense of place
 - Changes in agricultural practice as a result of climate change could significantly change the character and layout of existing farmland
 - Drying / alteration of wetlands would also change current character and could damage cultural heritage
 - Recreation potential and demand may increase in the NCA due to warmer, drier summers
 - Loss of significant access and recreation assets as a result of sea level rise (Hawes Water, RSPB Leighton Moss, coastal assets)
 - The impacts of climate change have the potential to be used to contribute to knowledge systems, in that local examples of real change as a result of shifts in the climate provide excellent teaching aids to help translate the abstract concepts of climate change into quantifiable, easily understandable effects.

Impact of other responses to climate change

- **Supporting services:**
 - See above for impacts on biodiversity
 - Potential effects on pollinators if more pesticide-intensive agricultural regimes adopted
- **Provisioning services:**
 - Need to relocate settlements and infrastructure could create competing demands for productive agricultural land
 - More extensive adoption of biofuels to reduce oil consumption and carbon emissions could compete with food production for better quality land – particularly if financial incentives for these crops are made available
- **Regulating services:**

- Installation of hard sea defences is likely to result in ‘squeeze’ of saltmarsh as sea levels rise, resulting in significant carbon release and the loss of the buffering effects against wave action
- Use of hard flood defences on river systems will affect the ability of natural floodplain processes to attenuate the speed, power and intensity of flood events – likely to displace damaging effects rather than avoid
- **Cultural services:**
 - Development of coastal flood defences or poorly planned large-scale marine renewables could adversely affect landscape character and sense of place
 - Installation of flood defences around settlements could impact on historic character and recreation potential

3 Integrated adaptation strategy

INTRODUCTION

- 3.1 The process of identifying valued assets and their potential vulnerability to climate change provides the first steps in developing a strategy by which the environments of the Morecambe Bay Limestones NCA can be protected and enhanced. Although the majority of actions required to build adaptive capacity offer cross-cutting benefits ('win-win' options) to a range of interests, some responses have the potential to generate conflicts which, if not appropriately managed, could result in adverse effects.
- 3.2 Therefore developing an integrated response to climate change adaption which effectively balances the needs of the natural heritage as a whole is imperative. The 'response screening' exercise is an opportunity to highlight areas of tension and adjust adaptive measures to take account of competing interests. Given the range of scales and severity of climate change impacts, a similarly multi-scaled approach to tackling these challenges is required. Responses are therefore grouped into one of three categories:
- Strategic approaches: providing a broad integrating framework to shape policy and future implementation
 - Sectoral responses: focussed on specific themes (e.g. biodiversity or access and recreation)
 - Site-specific responses: measures which need to be implemented to help a specific area or asset in the NCA adapt to predicted effects (e.g. a river valley or section of coastline)

PRINCIPLES FOR CLIMATE CHANGE ADAPTATION – AN NCA APPROACH

- 3.3 The following principles, guiding the proposed approach to adaptation, were generated through discussion between key stakeholders with detailed local knowledge. The principles are intended to steer the development and implementation of responses to provide consistency and to ensure that landscape character remains at the heart of the approach.
- i. Maintain and enhance local distinctiveness and landscape character to ensure valued assets are retained, whilst deriving a range of ecosystem services:**
- The coastal zone – notably the intertidal flats, saltmarsh and beaches
 - Key wetland features – remnant lowland raised bogs, fen, open water habitats and rivers
 - Karst features – limestone pavement, caves, poljes, and distinctive habitat and species assemblages

- Historic assets – prehistoric remains, designed landscapes, medieval tower-houses and villages and historic field patterns

ii. Accept that some landscapes will change, but seek to maintain the value of the landscape

Landscapes are dynamic and constantly evolving, particularly in coastal areas, where landscape change is inevitable. We need to plan and manage this change to respond to society's changing needs and values, whilst seeking to maintain valued properties, functions and services.

iii. Understand the interrelationship between neighbouring character areas and, where appropriate, undertake cross-boundary action

The Morecambe Bay Limestones cannot be considered in isolation, particularly in regard to developing an integrated response to river catchments, in addressing issues such as flood management, coastal realignment and enhancement of habitat networks. The character and significance of the Bay's processes depend on river systems rising outside the NCA and the development of habitat networks will require coordination with a number of local authorities and the Lake District National Park Authority

iv. Seek to create an ecologically resilient and varied landscape

Opportunities should be sought to enhance habitat heterogeneity, to support microclimates to help facilitate the adaptation of existing species within their current range and also to support permeability to enable movement of species. The topographic variation within the NCA has considerable benefits in that it creates a range of microclimatic conditions and has the potential to facilitate habitat succession (e.g. from south- to north-facing slopes)

v. Pursue opportunities for enhancing the value of the landscape through change

Landscape change is inevitable and need not be a negative process. It can be managed positively to enhance existing values and to create new opportunities for enhancing character, biodiversity values, aesthetic qualities and ecosystem services. There is significant potential for wetland creation and succession, providing opportunities for habitat improvement, carbon sequestration and water quality enhancement. Similarly, opportunities for creating new woodland habitat networks have the potential to both lock up carbon and assist the migration of species in response to climate change. Re-wetting initiatives in the Kent and Lyth Valleys will have significant flood attenuation benefits and will create important opportunities for habitat succession over the coming century, ensuring wetland species

prevail.

vi. Integrate climate change adaptation and mitigation measures into landscape management, planning and practice

Identify adaptation responses that will help the overall ecosystem become more resilient and have multiple benefits for landscape and other environmental assets. Where possible, identify and make changes to land management that reduce green house gas emissions and/or aid the sequestration of carbon. Preservation of existing and facilitating the development of new saltmarsh provides an opportunity to safeguard a significant carbon store. Similarly, carbon stored in organic (particularly peat) soils can be more effectively sequestered where they are kept moist – storing excess winter rainfall to compensate for increasingly dry summers.

vii. Identify and respond to the indirect impacts of climate change

The indirect impacts of climate change are likely to have a greater impact on landscape than direct effects. It is therefore necessary to effectively predict and respond to likely adaptive responses and ongoing mitigation measures to ensure that the NCA's assets are suitably protected. Within the NCA, these impacts are likely to relate to:

- Potential intensification of agriculture (shift to arable from pastoral systems) – pressure to amalgamate fields; intensive chemical use; new crop varieties – deeper rooting to cope with drought and energy crops (*miscanthus* and short rotation coppice) significantly changing landscape character
- Construction of new coastal defences leading to coastal squeeze – major decisions will have to be made regarding the protection or relocation of infrastructure such as the railway line
- Reduction/cessation of pumping in low-lying agricultural areas – notably the Lyth Valley – as fossil-fuelled pumping become less viable (could be replaced by renewables-power equivalents, but with significant landscape impacts – particularly for wind turbines)
- Increasing number of renewable energy installations within the NCA's visual envelope – offshore and onshore wind; potential for tidal stream or barrage construction?
- Changes in species choice and provenance in plantation forests for subsequent rotations, on exposed or droughty soils – tackling susceptibility to windthrow and stress

viii. Make sound decisions based on robust analyses

Adopt an evidence based approach which recognises that climate change is not the only driver of landscape change. By thoroughly analysing the causes of landscape change we will identify those situations where climate change adaptation is needed. A comprehensive understanding of the landscape can help provide an integrating framework for the management of change. The recent Regional and Arnside and Silverdale AONB landscape characterisation work will be useful in developing this understanding.

ix. Approaches must be flexible and not limit future action

Adaptation solutions should avoid committing us to a single pathway; adopting the principle of adaptive management provides the necessary flexibility and allows new approaches to be tested and monitored at the appropriate scale so we can learn from experience and revise our approaches accordingly.

x. Decisions should be based on a whole system approach and not focused on individual sectors

Action in one sector must not unreasonably limit the ability of another sector to adapt and thus shifting vulnerability from one actor to another. Similarly adaptation responses must not unreasonably increase green house gas emissions. Responses should be sought which achieve multi-objective benefits e.g. creation of a new wetland providing biodiversity, amenity and flood management benefits.

ADAPTATION ACTION PLAN

Introduction

- 3.4 The outcomes of the impact assessment and response screening processes produced a suite of actions which should be taken forward to safeguard the special character of the NCA and build resilience to the effects of climate change.
- 3.5 Given the multi-scalar nature of climate change impacts, a scaled spatial and strategic approach is required to adequately address the challenges they present. The action plan is therefore divided into:
- **Strategic actions:** focused on building institutional capacity and integration
 - **Sectoral/thematic actions:** required to address the adaptation needs of the NCAs ecosystems on a general level
 - **Site-specific actions:** interventions required to protect and enhance key assets, and to build resilience and succession capabilities for specific species and habitats
- 3.6 Inevitably, there is a considerable degree of read-across between sectoral actions – highlighting the desirability of integration and partnership working

between key actors, agencies and communities. The implementation of strategic actions will be critical to ensuring a coordinated institutional response to the key issues in the NCA and the wider region, and in building public understanding of issues and support for action. Ultimately, political buy-in and leadership is required, and bringing communities on board (enabling them to translate their concerns into pressure on their elected representatives) will provide the impetus for real, coordinated action.

- 3.7 The site-specific actions proposed below reflect the broad principles defined in the strategic and sectoral actions, and represent key mechanisms to contribute their achievement. They were developed and agreed by local experts and stakeholders, tying into existing work and highlighting opportunities for synergy.

Strategic actions

- 3.8 In partnership with stakeholders a number of strategic actions have been identified which are designed to provide an overarching framework to delivering adaptation within the NCA.
- A focus on **catchment-scale management and adaption** is necessary, looking beyond the boundaries of the NCA to build partnerships and implement measures to support integrated water management and flood attenuation. Potentially hard decisions regarding future land management options, washland creation/restoration and hard defence requirements must be made – harnessing natural processes will be a key mechanism, and securing benefits for the natural heritage will require coordinated action with other sectors
 - **Build climate change into the spatial planning agenda** – while climate change is acknowledged as a major challenge in recent legislation and national planning policy, work remains to be done in fully integrating the agenda in local policy frameworks and decision making. There are major opportunities to build climate change adaptation into Local Development Frameworks: policies encouraging the development of green infrastructure have a particularly important role to play in ensuring that new development contributes to local resilience and delivers community and landscape benefits. As part of this approach the existing or potential functionality of sites should be mapped and considered in terms of their ability to support climate change adaptation whilst also enhancing biodiversity within the NCA.
 - **Development of multifunctional wetlands** within the NCA must be a priority as they have the potential to address a range of objectives. Providing climate space for extant wetland floral and faunal communities to move in response to climate change will be critical in maintaining the special qualities of the NCA. As existing mosses and fens are affected by drying and potential salination of groundwater, providing the space for freshwater communities to migrate and enabling the influx of saltwater and more southerly

species. Selecting sites for rewetting and habitat creation will require partnership working across sectors and in close cooperation with communities and landowners. Creating new wetland areas will enhance the water retention potential of catchments and provide natural flood attenuation. They will also be critical in storing surplus water (resulting from increased winter rainfall) to compensate for summer droughts. During low flow events, the filtering role of reedbeds will be important in maintaining water quality. Similarly, such sites are important carbon stores, so creating further opportunities for sequestration will be an additional benefit.

- **Understanding and responding to land use change** within the NCA will be critical in planning and implementing the development of habitat networks, species succession and, where appropriate, translocation. It is likely that the NCA will experience significant levels of change in land use in the coming decades. Although a wholesale switch to intensive arable farming is unlikely, there will be increased pressure on better quality land. Energy imperatives may drive a move towards wider adoption of energy crops, with consequent impacts on landscape character. Similarly, 'squeeze' of important coastal grazing could impact inland resources, while loss of productive land to realignment and floodplain restoration will further intensify pressure on available land. The key objective will be to ensure that opportunities for natural heritage preservation and enhancement are secured through partnership working with land owners and managers. The delivery of future High Level Stewardship agreements have the potential to assist in the delivery of climate change adaptation focusing on the value of wetlands, flood storage, carbon sequestration and green infrastructure, as well as supporting farmers seeking to improve the resilience of their businesses.
- There is a need to **increase public awareness and understanding** of the potential impacts of climate change. Decision-makers, and landowners and farmers have a key role in developing appropriate policies and taking action. Effectively conveying key messages is critical in securing public and landowner buy-in to adaptation projects. A landscape-scale approach is particularly useful in this regard as discussing predicted impacts in a local, understandable context allows people to make the connections between the abstract concepts of climate change and the likely effects on their communities and the landscape they value. Placing the natural heritage and ecosystem services at the heart of this approach – clearly illustrating the 'free' functions which will be lost, at significant economic, social and environmental cost – will highlight the wider importance of securing the development of green infrastructure and habitat networks. Coordinated leadership from the natural heritage sector can assist in ensuring that biodiversity, landscape and historic interests are appropriately represented. However, securing local political consensus, support and leadership on the issue will be an important

mechanism in reinforcing the perception that climate change is a 'mainstream' issue and should be of major concern to everyone.

- **Monitoring change and the effectiveness** of adaptation measures is central to the success of an adaptive management approach. Further work is needed to map and research the vulnerability of assets to climate change as knowledge is still incomplete. Impacts on biodiversity (at a systems, rather than species level) and the historic environment are particularly poorly understood. Long term data sets and studies assessing environmental change will also be very important to inform adaptive management. The future implementation of the Biodiversity opportunity mapping can reduce the future impacts

Sectoral actions

- 3.9 In assessing the vulnerability of assets, responses were identified for key assets under the themes. The most vulnerable assets and key responses were identified in partnership with stakeholders. Each of these responses has been screened to identify potential conflicts and synergies with other objectives.

Biodiversity

- Managing and enhancing the quality and climate resilience of existing habitats to maximise their potential to withstand/adapt to climate change.
 - Seek to eliminate non-climate change related sources of stress and damage to valued assets. The legacy of past sources of pressure on the natural environment may restrict the ability of habitats to respond effectively to climate change, such as agricultural diffuse pollution, water abstraction or development leading to habitat fragmentation.
 - Conserve protected areas and other high quality habitats, making provision for shifting boundaries in response to climate change. Management plans should adopt an adaptive approach, adjusting existing practices to build resilience and monitoring results
 - Seek opportunities to build habitat connectivity through conservation of existing assets, restoration of degraded areas and creation of new areas of habitat. Integration with the planning system could create opportunities for developer funding of habitat network/green infrastructure development – particularly in connection with major development proposals/compensatory provision for lost habitat
 - Undertake detailed monitoring of resident and transient species to track population, distribution and migration change. Conservation objectives may have to change in response to patterns of climate change-driven migration – species currently considered to be invasive/exotic may have to be prioritised in

response to national/international imperatives (e.g. range squeeze, habitat scarcity or population decline)

- Allow for coastal realignment and ensure adequate space and sediment for shoreline adjustment through natural coastal processes unhampered by coastal defences
 - Create space to prevent ‘squeeze’ of saltmarsh between the high water line and infrastructure/hard defences
- Ensuring adequate land provision to enable succession of wetland environments/habitat creation – landscape/catchment-scale management
- Undertake monitoring of pest and disease activity and prevalence of harmful invasive species and develop responses appropriate to conservation objectives
- Enhance habitat heterogeneity to allow species to exploit microclimatic variations.
Responses include planting a mixture of woodland trees and increasing riparian shade through flood plain planting. The creation of transitional habitats between grassland and woodland will also provide increased variability of habitats and microclimates.
- Proactive development of large-scale habitat recreation as part of enhancing the green infrastructure within the NCA, with a focus on wetland creation schemes and supporting the roll-back of coastal habitats including salt marsh
- Identify areas in river catchments for floodplain restoration, wet and riparian woodland creation to enhance habitat connectivity, help reduce runoff and assist in flood attenuation.
- Build regional catchment-scale partnerships to reduce agricultural/urban/infrastructure runoff to limit potential for diffuse pollution – reducing additional stress on wetlands
- Reappraise boundaries of protected sites, particularly in coastal areas and wetlands threatened by saline incursion
- Learn and apply lessons from past extreme weather events (e.g. severe floods or heatwave) on the impacts on key species and habitats and develop measures to boost resilience – potential to apply knowledge from southern England and continental Europe with climatic conditions similar to those which occur in the NCA in future
- Undertake a detailed ecosystem service assessment for the NCA to better understand the functionality of existing green infrastructure and to highlight areas of weakness and opportunities for enhancement

Geodiversity

- Influence and contribute to the development of the next generation of Shoreline Management Plans to support the development of a naturally evolving coastline:

- Highlight investment priorities for further research into key formations and processes likely to be affected by climate change:
 - Karst features
 - Aquifers vulnerable to salination (potentially affecting fen habitats)
- Strongly discourage development in floodplain locations and raise awareness of vulnerabilities:
 - Work in partnership with planning authorities to highlight importance of properly functioning washlands and to develop robust policies to prevent inappropriate development
- Influence flood defence schemes to facilitate natural river processes
- Review site boundaries of existing coastal geological SSSI in order to identify where boundary changes are appropriate for the management of geological features in future
- Encourage positive change in land management practices to reduce impacts on soil structure and maintain organic content/carbon store
- Adopt land management practices to maintain and improve water filtration to reduce the risks of diffuse pollution
- Encourage adoption of measures to reduce soil erosion caused by both water and wind, e.g. buffer strips, increase in organic matter, increase vegetation cover, reinforce existing and create new hedgerows and shelter belts (contributing to habitat networks)
- Adopt management practices to restore groundwater levels to enhance moisture content of fen and mire peat within the NCA

Access and recreation

- Effective planning to ensure access and recreation infrastructure is sufficiently robust to deal with potential increase in visitor numbers and the effects of climate change
 - Building partnership between responsible bodies (government agencies, NGOs, local government, voluntary organisations)
 - Coordinating action and funding to create new infrastructure and to secure fragile areas – reducing pressure on local authority Rights of Way budgets
 - Drainage improvements
 - Reinforcing popular routes, bridges etc.
 - Ensuring provision of alternative/replacement routes for vulnerable coastal access infrastructure which may be lost or rendered largely unusable

- Longer growing seasons will increase need for maintenance on rights of way and greenspace. Increased woodland management, hedge cutting and ditch clearance will also be necessary
- Promote sensible and responsible recreation, particularly in periods of heat-waves where there is increased risks to health as well as risks of wildfires in grass- and moorlands, beaches and woodland (key recreation areas)
 - The risk of underground peatland fires during drought conditions is likely to increase, even in lowland mosses which have – until now – been relatively low-risk locations. Existing wildfires work in Cumbria should be expanded to cover these newly-vulnerable areas.
- Build partnerships with public transport providers and roads authorities to develop sustainable and low carbon transport networks
- Ensure development of coastal access provision, introduced under the Marine and Coastal Access Act 2009, is proofed against likely climate change impacts, particularly regarding coastal squeeze, sea level rise and more severe/more frequent storm events.
- Further promote cycling routes throughout the NCA and develop partnerships to provide new infrastructure for cycling that provides routes away from roads.

Historic environment

- Work in partnership to undertake/commission comprehensive surveys of:
 - Areas vulnerable to direct effects of climate change, particularly the coastline and intertidal zone
 - Areas where mitigation/adaptation measures will be required (managed realignment, floodplain restoration, flood defences, woodland expansion and habitat network creation)
 - Historic plantings in designed landscapes
 - Vulnerable assets to enable monitoring of effects of climate change
- Use quality data (gathered from above) to feed in to:
 - Targeted recording programmes to ensure preservation by record of sites which will be lost to coastal realignment etc.
 - Appropriate protection, enhancement, management and, where necessary, planned replacement of historic plantings in designed landscapes. Selecting appropriate species/provenances for succession plantings where climate change makes like-for-like replacement unviable – maintaining character and biodiversity value

- Protection strategies for historic buildings vulnerable to flooding or damage from increased physical and chemical weathering
- Management of soil, vegetation and agricultural attrition through agri-environment schemes to protect buried sites likely to be damaged through changes in land use e.g. shift towards arable
- More intensive maintenance of rainwater goods on historic buildings – monitoring to determine whether higher-capacity goods may be required.
 - Assess need for pilot projects designing and installing higher-capacity rainwater goods, enhanced soakaways and water storage infrastructure (may be particularly useful in historic gardens where summer water shortages could affect plantings)
- Opportunities should be sought to enhance the flood resistance of the built environment using techniques such as flood guards and flood-resilient materials appropriate to the age, materials and structure of the building
- Influence the development of flood defences required to protect historic settlement

Landscape

- Make use of the Shoreline Management Plan process to secure space to enable habitat succession for coastal wetlands as shoreline is realigned and fens/mosses are affected by salination (e.g. assisting species and habitat movement from Leighton and Storrs Moss inland to White Moss and Hale Moss; developing new wetland areas in the Lyth Valley to ensure long-term resilience
 - Highlight key opportunities for habitat/green infrastructure creation through managed realignment
- Adopt a landscape-scale approach to:
 - Managed realignment around the Bay – seek to influence strategic decisions regarding removal / strengthening coastal defences
 - Ensure that losses of saltmarsh can be sustained through assisted accretion elsewhere (construction of groynes etc. to trap sediments)
 - Wetland creation and habitat succession
 - Influencing land management practices to preserve and, where necessary, replace important features of agricultural landscapes (e.g. hedgerows, field trees, shelter belts)
 - Increasing water retention capacity within catchments to support and enhance existing wetlands and, where possible, restore hydrological connectivity between ditch systems and wetlands

- Build consensus behind a landscape character-led approach to adapting to climate change
- Influence the development of any flood defence proposals that seek to protect historic settlements

Ecosystem services

- Commission / undertake research into the amount of carbon sequestered within the environmental assets of the Character Area:
 - Fen and mire peat
 - Woodlands
 - Hedgerows
 - Saltmarsh
 - Intertidal flats
 - Historic assets and landscapes
- Develop a restoration strategy and timeline for reduction in CO₂ release from peat soils
- Integrated water management within catchments to respond to changes: attenuating impacts of excess winter water, storing to compensate for summer droughts
- Work in partnership with land owners and managers to encourage the adoption of sensitive farming methods to support water and soil conservation, protection of bird and natural pollinator populations by maintaining and increasing functionality where possible
- Support farmers through information and advice on diversification into new crops and breeds more resilient to emerging climate conditions, as part of an overall approach to encourage mixed sustainable farming which protect the natural assets of the NCA
- Identify opportunities to support appropriate renewable energy projects:
 - Identifying potential for developer contributions to habitat creation/protection initiatives
 - Investigate potential to supply woodfuel from woodland assets and hedgerows within the NCA, and research the sustainable productivity resources of woodland allowing for the balancing of fuel production and conservation enhancement such as 'log habitat piles'
- Increase the development of sustainable drainage systems able to intercept and store water, including retro-fitting in urban areas with existing surface water flooding problems

Site-specific actions

- 3.10 The responses detailed in the previous sections provide a framework for action across the NCA. It is intended that these responses will influence the policy and decision-making of key partners within the region. Natural England is also keen to develop pilot and demonstration projects to examine how responses to climate change can work on the ground. Clearly, these need to be undertaken at a higher resolution than that provided by this document. Developing and testing a range of specific responses will enable the development of a suite of appropriate tools to guide and implement adaptation, making a considerable contribution to the NCA's resilience.
- 3.11 Potential areas for pilot projects include the following sites, some of which are already the subject of preliminary studies and/or preparatory work:
- **Re-wetting**
 - Lyth Valley
 - Arnside Moss
 - Hale and Hilderstone Mosses
 - Methop Moss
 - River Keer, Warton
 - **Re-alignment**
 - Methop Marsh
 - Levens Moss
 - Winster Valley / Castle Head Marsh & Low Methop Marsh
 - Milnthorpe Marsh
 - New Barns
 - Quaker Stang, Silverdale
 - Sandside – moving employment zone into quarry when stone production ceases
 - **Access Infrastructure**
 - Multi-user route – Hincaster Trail extension to Arnside/Silverdale AONB
 - Cycle way from Carnforth to Crag Foot alongside railway
 - Cycle and footway across Arnside viaduct
 - Linking Milnthorpe Moss to Sampool and Foulshaw including bridle bridges across the rivers Kent and Gilpin
 - **Ecosystem Services**
 - AONB Low Carbon Landscape Project (this is in development and discussions are on-going to appoint consultants who will prepare a feasibility study and develop an action plan.

NEXT STEPS

- 3.12 Building resilience to climate change will not take place in a single burst of action or event – it will require a lengthy process of research, consultation and capacity-building. Similarly, actions are unlikely to provide ‘once-and-for-all’ solutions – detailed monitoring and constant review of plans will be required to ensure that management of assets and the landscape as a whole is truly adaptive.
- 3.13 This study should therefore be considered as a step in this process, providing a focus for engagement and a framework for action. It will be necessary for local experts and stakeholders to prioritise actions to ensure that effort is focused on the most vulnerable assets and on initiatives with the potential to add most value. Bringing forward, and effectively marketing, demonstration projects could have an important role in building public understanding and support – in addition to acting as ‘proof of concept’ for innovative habitat creation schemes. Similarly, involving community groups, voluntary conservation organisations and schools in such projects could promote valuable ‘buy-in’ and foster a sense of ownership of both the natural environment and of responsibility for its protection.
- 3.14 Bridging the gap between perceptions of ‘natural heritage sector’ activities and the social and political mainstream remains a major challenge. Building in awareness and appreciation of the importance of ecosystem services, particularly in relation to their role in flood attenuation – a major issue in the Northwest given recent events – has considerable value in highlighting the wider social, economic and environmental role of natural systems. Ultimately, climate change will affect the entire population to some degree, therefore any role which the sector can play in educating, informing and preparing local people will be of significant benefit.

