"We all need to act now - our future quality of life depends on it"

North East England Climate Change Adaptation Study

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ROYAL HASKONING

UK Climate Impacts Programme

THE NEED FOR ACTION

A degree of climate change is inevitable and there is a growing realisation that the UK will have to adapt. This is a summary of the North East England Climate Change Adaptation Study. The full report can be found at www.adaptNE.org. This study was commissioned to provide the detailed local knowledge necessary so that action can be taken to increase our resilience to climate change.

The adaptation study takes the assessment of the potential impact of climate change to a new level of detail. This means that North East England now has a clear picture of what changes are likely in the years ahead, what areas will be most affected and what we need to do now to prepare and adapt.

All sectors need to take note of the findings of the report and develop appropriate actions so we protect our quality of life and also gain competitive business advantage.

Background

There is mounting evidence that the UK is experiencing more unusual and variable weather. Models of what the climate might be like in the future suggest that events we now consider to be 'extreme' will become more commonplace.

Over recent years the UK has seen significant flood events, most recently across south Yorkshire, Humberside and Gloucestershire in the summer of 2007. These events tragically resulted in some loss of life and caused extensive flood-related damages to homes, industry and infrastructure.

Other notable events across the UK in recent years have included the record high temperatures during the 2003 heatwave and then again in 2006, and the tornadoes that affected Selsey Bill in 1998, Birmingham in 2005, and London in 2007, wreaking damage to infrastructure and buildings.

In recent years the UK Government has identified climate change as one of the greatest threats to society and has placed it high on the political agenda. There has also been much media interest in the topic, both in the UK and worldwide, and a recognition that action needs to be taken now to respond to the challenge posed.

In North East England, we too have suffered impacts from floods, wind, heatwaves and other weather-related incidents. These events are projected to increase by the 2050s under scenarios of climate change. In recognition of the threat posed, a number of North East organisations have formed the NE Climate Change partnership to take forward a study to better understand the climate changes, to assess the threats and impacts they pose and to identify how the region needs to adapt now to best manage these projected changes and impacts.

What is causing climate change?

Climate change is caused by a combination of both natural and human-induced factors. The Earth's climate varies naturally as a result of interactions between the atmosphere and the ocean, changes in the Earth's orbit, fluctuations in energy received from the sun and volcanic eruptions. Human activities also contribute towards climate change through emissions and changes in land use. A majority of scientists and Governments now believe that these activities are a major cause of climate change.

The climate change that will occur over the next 30 to 40 years has already been largely determined by past and present emissions of greenhouse gases. Once emitted into the atmosphere these gases can last for a long time and so can influence the climate system into the future. This means that even if emissions are vastly reduced with immediate effect the climate will continue to change in response to the legacy of emissions and adaptation measures will still be needed. This is why both mitigation (reducing greenhouse gas emissions through energy reduction, efficiency and innovative approaches) and adaptation (responding to the impacts caused by climate change) are important.

THE NORTH EAST CLIMATE CHANGE ADAPTATION STUDY

This Adaptation study has:

- Projected climate changes across the region to the 2050s using state-of-the-art modelling techniques;
- Assessed the impacts of the projected climate changes on current services, assets, communities, business and infrastructure;
- Identified what needs to be done to adapt to the impacts; and
- Identified which organisations are best placed to take the lead in taking forward the identified adaptation actions.

This information provides a catalyst and focus for action across all sectors operating across the region.

The practical advice provided in the Adaptation Action Plan, which is founded on sound scientific information, cutting-edge thinking and latest best-practice guidance, can be used by key organisations across the region in the development and delivery of their own climate change adaptation action plans.

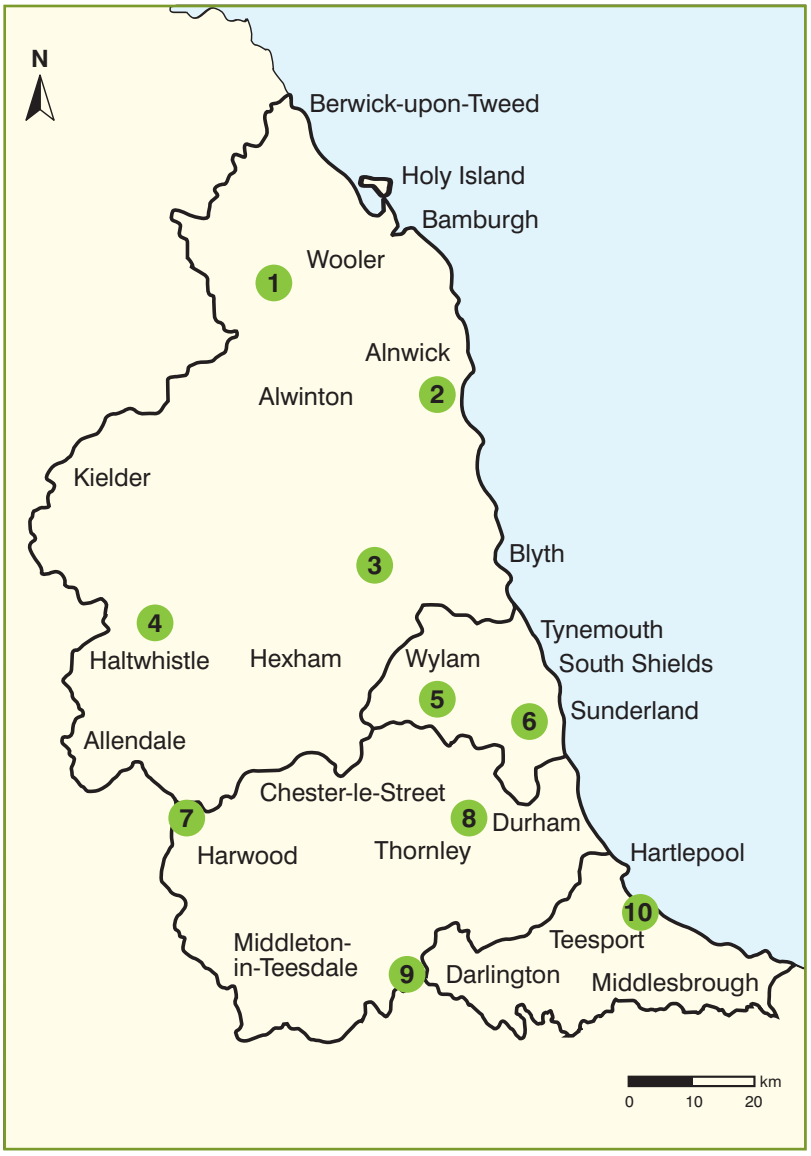
Future climate change projections

Assessments have been made using the Environment Agency's Rainfall and Weather Impact Generator (EARWIG) for ten locations across the region to determine the climate changes projected by the 2050s.

The EARWIG model operates at a 5km by 5km scale of resolution, which has enabled more detail to be provided than has ever previously been available across the region.

The ten sites cover both urban and rural areas and extend from upland locations, through inland locations to coastal areas, giving a good geographical coverage of the region as a whole (see map opposite).

In addition, extensive literature reviews, press cuttings reviews and supporting data analysis have been undertaken to complement the climate modelling.



Key projected findings from this assessment are:

- Annual rainfall reductions throughout the region by up to 10 per cent;
- Increased seasonality of rainfall with increases of up to around 21 per cent in winter and reductions of up to around 37 per cent in summer;
- Variability in extreme rainfall events, but increase of up to around 20 per cent will be felt in some areas;
- Average seasonal temperatures to increase, with a region-wide annual average daily temperature change of just under 2°C;
- Extreme hot temperatures will increase by around 3°C;
- Heatwaves are likely to increase in frequency of occurrence;
- A reduction in the number of frost days;
- A major reduction in winter snowfall, of around 45 per cent to 83 per cent across the region;
- There is variability in the projected winter wind climate, but small increases will be felt in some areas;
- An increase in mean sea levels of around 0.3m; and
- An increase in sea surge levels of around 0.30m to 0.35m.

Future impacts

The aim of this stage was to assess the impacts of the projected climate changes on the communities, businesses, services, infrastructure and economy within the region. This involved collating data and information relating to the key receptors that are located across the region, under separate sectoral headings of:

- Transport
- Public services
- Utilities
- Industry and business
- Heritage, tourism and leisure
- Flooding
- Coastal erosion
- Groundwater and mine water

The professional expertise of key project team personnel was then applied to assess the impacts caused by the projected climate changes to each sector. These personnel covered the following technical specialisms:

- Climatologists
- Hydrologists
- River, coastal and drainage engineers
- Mast and tower engineers
- Transport and highways engineers
- Structural engineers
- Geomorphologists
- Geotechnical engineers

The impacts assessments were then enhanced with local expertise and local knowledge from technical officers working for various organisations across the region. This was achieved through consultation workshops held in Gateshead, Middlesbrough, Morpeth and Newcastle-upon-Tyne.

Invitees included local authorities, utility companies, transport agencies, housing associations and heritage organisations, amongst many others. The aims of each workshop were to:

- Identify the assets managed or services provided by each organisation, noting locations, maintenance regimes, conditions, design standards, etc., where available;
- Identify any recorded or anecdotal trends in weather patterns over time;
- Consider historic impacts associated with weather events and assess how these may change over time with respect to climate change; and
- Consider adaptation that has taken place to date and what might need to be done in the future.

The principal climate change related impacts projected for the region by the 2050s are:

- Increased frequency of flooding from rivers, streams and the sea
- Increased adverse health and welfare effects during warmer summers
- Increased incidents of wild fires and parkland fires
- Increased frequency of flooding from drainage systems
- Increase in infectious diseases in humans and livestock
- Increase in pests
- Increased damage to fabric and structure of buildings
- Loss of business / service productivity or continuity
- Increased business opportunities associated with adaptation
- Increased pressure on emergency services
- Increased disruption to service continuity
- Increased pollution from contaminated land
- Increased erosion of the coastline
- Increased wildlife impacts on construction and maintenance activities
- Reduce adverse health effects during warmer winters
- Increased storm-related debris
- Increased footpath and cycle path erosion
- Changes in winter road maintenance regimes

These impacts are discussed in more detail below.

Increased frequency of flooding from rivers, streams and the sea

Changes in winter rainfall, extreme rainfall events, mean sea levels and surges will place increasing pressure on existing flood and sea defences and cause more frequent flooding of presently undefended areas. The standard of service provided by existing defence structures, where present, will reduce over time as the peak river flows and extreme sea levels increase with climate change, leading to increased likelihood of overtopping, overflowing or breaching of defences.

Due to the topography of many of the river valleys within the region, there will not necessarily be vast additional expanses of land flooded, but rather those areas presently prone to flooding will become more frequently affected, particularly during winter months. Regeneration and redevelopment in riverside areas susceptible to flooding will compound this problem by increasing the assets that will be at risk due to flooding.

Increases in the frequency of flooding will lead to the following impacts:

- Increased number of flood-related fatalities and injuries;
- Increase damage (directly) to buildings and infrastructure;
- Increased damage (indirectly) through lack of business continuity planning and/or disruption to the transport network;
- Increased health and welfare impacts due to personal stress and spread of water-borne disease;
- Increased disruption to service provision, for instance home-help to the infirm and elderly in remote rural areas; and
- Increased pressure on emergency response personnel coupled with finite resources such as boats and pumps.
- There could also be knock-on effects such as the potential for 'uninsurable' homes.

Increased adverse health and welfare effects during warmer summers

Rising temperatures and more heatwaves will have negative health impacts, particularly on vulnerable members of society, such as the young, infirm and elderly. The main impacts will be:

- Increased incidents of skin-related afflictions such as sunburn and skin cancer;
- Increased incidents of midge and tick bites leading to increases in vector-borne diseases amongst humans and livestock;
- Exacerbation of respiratory problems;
- Greater discomfort to passengers travelling on public transport especially trains where windows cannot be opened for ventilation and underground sections of the Metro service;
- Greater discomfort to residents, school pupils, college and university students, office and factory based workers and other people in confined spaces, such as prisoners;
- Increased heart problems due to heat stresses and heat stroke;
- Increased circulation problems such as deep-veined thrombosis due to reduced mobility of vulnerable people during warming weather; and
- Increased mortality rates due to heat-related effects.

All of the above factors will place increased pressure on the resources of emergency response units, hospitals, mortuaries and cemeteries.

These heat-related impacts of climate change will be further exacerbated by the changing population demographics of the region by the 2050s, with more people in the most vulnerable age group of over 75 years by this time.

National and international migration due to climate change may also fundamentally change the demography of the region.

Increased incidents of wild fires and parkland fires

Rising temperatures and reduced annual and summer rainfall will mean that grassland and moorland will at times be tinder dry. Fires will spread much more rapidly for instance where fires are started in urban parklands due to arson or carelessly discarded cigarette butts or in the remote moors and fells due to natural ignition or heather burning getting out of control. Tackling fires will become more difficult, increasing the threat to life and the environment, and placing high demand on finite fire-fighting resources.

Increase in pests

Rising temperatures will increase the number of breeding cycles of some unwanted pests and will also produce conditions more likely to be conducive to their presence and spread. In particular rats and maggots are likely to increase in urban areas as refuse is affected by high temperatures before it is collected and disposed of. This impact will be made worse by the ongoing trend of reductions in frequency of collections in some local areas.

Elsewhere, the changing wetting and drying patterns of structures associated with changes in rainfall intensity and temperatures will result in more wet rot and dry rot in buildings susceptible to water ingress due to lack of maintenance. Also, there will be increased likelihood of insect infestations such as wood-boring beetles in buildings containing timbers, including many of the structures of key heritage interest across the region.

Increased frequency of flooding from drainage systems

Increases in winter rainfall and intense rainfall events will lead to increased frequency of flooding from existing drainage systems, many of which are Victorian in age in the more urban areas of the region. This will be caused by surcharging and back-up flooding as the capacity of systems is exceeded. Along with the projected climate changes, this issue is compounded by the fact that most systems are designed to relatively modest standards (for example 1 in 30 year return period events). There is also an increasing trend for floodplain redevelopment and paving of gardens to enable more vehicular parking at residential properties, which significantly reduces the permeability of the urban catchment and results in greater surface run-off into the drainage systems.

Increase in infectious diseases in humans and livestock

Rising temperatures will result in increased abundance and longer survival of midges and ticks that can spread infectious diseases amongst humans and animals. Whilst some commonly cited vector-borne diseases such as malaria are problematic on a global scale they are highly unlikely to be experienced in the North East region by the 2050s. There will, however, be increased likelihood of tick-borne diseases such as encephalitis and Lyme disease as well as faeco-oral diseases such as diarrhoea in humans, largely contracted in more rural areas. Also in these areas, there is likely to be increased tendency for vector-borne diseases such as bluetongue amongst cattle, sheep, deer and goats.

Increased damage to fabric and structure of buildings

Increases in winter rainfall, temperature and (very small) winter wind speed will result in more damage to the fabric and structure of buildings through impacts such as material expansion, water ingress and dislodged elements.

Large parts of the region have antiquated (e.g. single-glazed) and poorly-maintained or derelict building stock, especially public-sector housing and schools, which will be particularly vulnerable to these impacts.

Loss of business/service productivity or continuity

Rising temperatures will lead to uncomfortably hot working conditions in many interior-based businesses or services, meaning that efficiency and productivity will be reduced. Computer and mechanical failures will occur more often due to operating in high internal temperatures, especially in under ventilated areas.

Those businesses dependent on continuity of transport connections will also be affected by increased frequency of flooding disrupting key road and rail links.

During events of a significant magnitude, which are set to increase in frequency such as winter flooding or summer heatwaves, there will be pressures on organisations both for responses and for information. This increased demand will at times overstretch the available resources.

Increased business opportunities associated with adaptation

Rising temperatures will make the region an even more favourable destination for tourists as other destinations worldwide become uncomfortably hot. This will have positive impacts on tourist-related businesses.

In addition, the warmer climate will encourage increased recreational use of the region's beaches, riversides and upland moors and fells.

Some of the additional or new resources required by the region to adapt to the impacts of climate change (e.g. personal protective equipment, pumps or boats for flood responses) can be manufactured within the region and training can be provided in their use and maintenance.

Rising temperatures and changing rainfall patterns will mean that arable land can be used for growing different crops, such as grapes or even oranges, placing new products on the regional market.

The region is also very well placed to capitalise on business opportunities associated with the mitigation agenda through its leading-edge work in renewable energy, bio-fuels, low carbon power generation and waste and energy management.

Increased pressure on emergency services

With the anticipated impacts associated with flooding, heatwaves and wildfires in particular, the emergency services will become progressively stretched in responding to an increasing number of events. There is a major risk that the services will become over-stretched, that insufficient resources will be available to adequately respond to each event and that the services will not be equipped with appropriate tools. For example, in order to adequately respond to remote moorland wild fires, there is a need for off-road vehicles and supplies of water that can be used for fire-fighting. Similarly, to assist with an increasing number of flood events, the demand for sandbags, boats and high-pressure pumps will increase.

Numerous simultaneous incidents, which often happen with weather-related events, will further stretch the services requiring a pan-regional and inter-regional working approach.

There is also the risk that if services are increasingly deployed on 'secondary events' such as small scale local flooding or small parkland fires, then they may not be able to respond to a major event that occurs at the same time.

Increased disruption to service continuity

In many parts of the region, some people are critically dependent on public, private or voluntary sector support in terms of medical and welfare assistance. This includes 'at home' services, such as Meals on Wheels or nurse/midwife/doctor visits to people's homes, and transport to and from day-care or social activity centres. Increased frequency of flooding will adversely affect the ability of services to be provided to these vulnerable people, particularly those in remote rural areas.

At present across the region there are notable disruptions from wind-blown debris blocking road and rail networks, and striking power lines causing disruption to electricity supply. Whilst the risk of this is only very slightly greater by the 2050s than the present day, the risk of such an incident coinciding with a flood event is greater (since the frequency of flooding is set to increase with significant changes in winter rainfall), placing people in need of medical and welfare assistance at even greater risk.

Increased pollution from contaminated land

Much of the region has a former heavy-industry heritage and as a result there are considerable areas of land containing contaminated soils, usually engineered in some way to make them safe unless the soils are disturbed. The significantly increased rainfall in winter will lead to some of this material leaching from contaminated sites or being eroded from sites adjacent to river banks due to increased winter flows through the river channel.

Similarly, increased sea levels will increase the release of hazardous material from former landfill sites located along the coastal margin, presenting both public health and safety and environmental risks at the point of discharge, and more widely when dispersed into the sea.

Increased erosion of the coastline

Increasing mean and extreme sea levels will result in the erosion of the coastline in areas composed of softer sediments like sand or mud, as opposed to harder rock. This means that beaches and dunes will migrate landward and soft cliffs will recede. In many places, this will result in loss of open space or agricultural land, but elsewhere assets such as cliff-top roads and footpaths, as well as isolated properties or small communities will be affected.

Increased wildlife impacts on construction and maintenance activities

Changes in growing seasons of flora and breeding seasons of fauna will have direct effects on maintenance activities such as grass and hedgerow cutting. Crews will need to maintain parks and roadsides for longer each year. They may also be constrained in the timing of maintenance and construction activities by elongating 'wildlife windows' when such activities are forbidden due to their perceived adverse wildlife impacts (e.g. nesting, roosting or over-wintering birds). This causes impacts in terms of resourcing and programming of essential maintenance and construction activities.

Reduced adverse health effects during warmer winters

Rising mean and extreme temperatures will result in fewer cold-related deaths and illnesses during winter months, but this is unlikely to be as significant as the adverse heat-related changes since winter temperatures will still, at times, drop below freezing.

Increased storm-related debris

The large increases in winter rainfall and the very small increased changes in winter wind speed will result in more storm-related debris. This will include very minor increases in incidents of blown-trees striking power lines and buildings and blocking road and rail networks, a presently common occurrence across the region during storms. It will also increase the blockage of drains, gulleys, culverts and trash screens by sediment, debris and litter resulting in increased maintenance requirements in terms of gulley suckers and manual clearance to avoid the very real risk of blockage-related 'back-up' flooding.

Increased footpath and cycle path erosion

Increased winter rainfall and intense storm rainfall could directly lead to runoff that will erode parts of the region's countryside public footpaths and cycleways. These are key assets to the region's tourism and recreation economy, and this erosion could be further compounded by the increased use of these facilities due to increasing temperatures. Generally, the countryside cycle paths are of a basic design comprising hardcore and shale dusting and the public footpaths are simple worn tracks, making them particularly susceptible to erosion.

Changes in winter road maintenance regimes

The large projected reductions in snowfall across the region will mean that snow-ploughing and gritting or salting to clear snow from key roads will be required far less frequently by the 2050s. However, there will still be some snowfall occurring therefore road maintenance crews cannot do away with snowploughs altogether.

Also, winter rainfall is set to increase and with winter temperatures still dropping below freezing, pre and post gritting/salting against ice will continue to be required. More 'marginal' calls for gritting may well be expected and grit life on roads may be reduced by increasing frequency of wash off.

ADAPTATION

In combating climate change there is a need for regional action in terms of both adaptation and mitigation.

Adaptation – focuses on ensuring services, assets, communities, businesses, infrastructure and the economy are resilient to the realities of a changing climate.

Mitigation – focuses on reducing the emission of greenhouse gases through energy efficiency measures, the Kyoto Protocol, regulation and control, etc. in attempts to reduce the rate of climate change.

It takes a long time for the Earth's climate system to reflect changes in our actions and we are already tied into their inevitable consequences through the climate changes that will occur over the next 30 to 50 years. These changes have largely been governed by the greenhouse gas emissions that have already occurred over recent historic time and remain ongoing. This is why adaptation is important now to provide resilience across the region to these changes. **It is critical that both adaptation and mitigation are undertaken at the same time.**

Current weather events cause considerable economic loss due to direct damage and disruption, which in itself causes indirect damage and losses. In an average year, around £800 million is paid out by insurers in weather-related claims. In a year with exceptional events, this can rise to around £10.5 billion. During the summer 2007 flood, it has been estimated that around £5 billion of economic damage was caused. The principal causes of weather-related damages are subsidence, storm-damage, inland flooding and coastal flooding.

In its publication 'Insuring Our Future Climate: Thinking for Tomorrow, Today' the Association of British Insurers (ABI) has estimated that by the 2050s the payouts during an average year will rise to around £2.2 billion and payouts during a year with exceptional events will increase nearly three-fold to around £29.2 billion due to the effects of climate change alone (i.e. not taking into consideration other changes such as new buildings, more material possessions in homes, etc.). This research indicates the broad scale of cost that inaction against climate change will have for the UK as measured by insurance payouts.

Additionally, the high profile 'Stern Review on the Economics of Climate Change' suggests that if no action is taken, the overall costs and risks of climate change will be equivalent to losing at least 5 per cent, and possibly as much as 20 per cent, of global Gross Domestic Product (GDP) each year now and in to the future. In contrast, the cost of action (here measured through the benefits of mitigation and adaptation, rather than adaptation alone) are around 1 per cent of global GDP each year.

The European Environment Agency has recently published a technical report entitled 'Climate Change: The Cost of Action and the Cost of Adaptation' in which it is identified that:

- adaptation has an extremely important role in reducing the economic costs of climate change; and
- whilst adaptation has a cost, it significantly reduces the enduring costs of climate change.

All of these previous studies highlight the importance of adaptation actions now in more than offsetting the economic consequences of inaction later.

To assist organisations in identifying suitable adaptation approaches, a number of adaptation tools are available. The 'UKCIP Adaptation Wizard' is one such tool that provides information from the latest research projects and covers a wide range of sectors. Other industry guidance documents are also available relating to best practice in adaptation for specific sectors such as business or flood and coastal defences. Many of these documents focus on an '**ABC**' approach, encouraging:

Adaptation	**B**usiness continuity plans	**C**o-operation

All of these approaches are highly relevant in the North East region in adapting to the impacts from projected climate changes by the 2050s. Adaptation can best be achieved by linking appropriate measures into planned maintenance activities and all capital investment projects.

Adaptation Approaches for North East England

We recommend the following key adaptation strategies for countering the projected impacts from climate change across North East England by the 2050s:

- Gather and share information on climate change trends, impacts assessments, and adaptation activities across the region
- Risk awareness and risk-based management
- Inspection, monitoring and maintenance of assets
- Physical adaptation in the use or structure of buildings and in infrastructure
- Warnings to enable preventative actions
- Prioritisation and delivery of adaptation actions
- Resource planning and management
- Increased use of novel technology and the need for further innovations
- Influence long-term planning
- Encourage cross-sectoral, partnership-based awareness and responses
- Exploit the opportunities presented by climate change
- Lobby for change
- Review the effectiveness of adaptation approaches and revise as necessary

These strategies are explained in more detail below.

Gather and share information on climate change trends, impacts assessments and adaptation activities across the region

Whilst climate models are available to make projections of future climate (e.g. UKCIP02, EARWIG, and the forthcoming UKCIP08), ongoing weather monitoring and data analysis will prove vital in monitoring the actual observed directions and rates of change in different weather aspects, such as rainfall, temperature, sea level rise, and wind. These data, when measured over the medium- to long-term can provide information about the trends in the region's climate. This information can be useful in impacts and adaptation studies and in calibrating model projections to identify whether actual changes are occurring faster than projected.

Sharing information about ongoing impacts assessments and adaptation activities will lead to a wider range of organisations thinking about climate-related problems, and solutions to them, in a different way. This will enable opportunities for collaborative approaches to be identified, which can be more effective than individual approaches and will lead to dissemination and wider uptake of best practice across the region.

The present study is intended as a first step towards delivering this adaptation strategy across the region, but needs to be followed by further action.

Risk awareness and risk-based management

Organisations and businesses operating across the region, including public, private and voluntary sectors, all need to understand the risks posed by climate change in order to manage those risks suitably to ensure least-possible disruption to service provision or business activity.

Some individual organisations based within the region have already undertaken 'high level risk assessments' to broadly identify the risks posed to their services or businesses by the climate changes projected for the 2050s (or other time epochs). These, in some cases, have then been further supported by more specific detailed assessments at the sites of particularly vulnerable assets or services. An example of good practice in this respect has been set by Northumbrian Water. This approach needs to be more widespread across the region so that individual organisations and businesses are better informed and better prepared for the challenges ahead.

The development of business continuity plans is a useful means to identify the risks posed to specific services and businesses at an appropriate level of detail and for developing risk-based approaches to both strategic (long-term direction) and operational (day-to-day) management. Such plans should identify clear roles and responsibilities within each organisation or business for developing the adaptation strategies and delivering the physical 'on-the-ground' adaptations in advance of impacts occurring.

Some organisations, such as Network Rail, already develop and implement a seasonal preparedness plan, which effectively is a specific business continuity plan for a particular sector. This enables both immediate and longer-term threats to be identified and pro-active and re-active management approaches set out. With the projected climate changes other services that are particularly vulnerable, or which will become increasing vulnerable, to seasonal changes would benefit from similar plans. This particularly relates to the health service sector which will face different challenges by the 2050s compared with the present day due to rising temperatures in particular.

Inspection, monitoring and maintenance of assets

It is essential that inspection or monitoring of assets is undertaken across the region to identify signs of deterioration that could leave assets more exposed to weather-related damage, disruption or failure under the climate changes that are projected. Where this monitoring identifies signs of deterioration or weakness, maintenance will be required to bring assets back up to a suitable condition or standard of performance. The inspection/monitoring and maintenance requirements will increase over time due to the changing climate and this has clear resource implications for organisations.

Inspection and monitoring will be required to cover a wide range of factors, including the identification of weakness in the fabric or structure of buildings or infrastructure, trends in the number of pests or diseases (e.g. sheep ticks, Lyme disease in humans, etc.), and condition assessments of flood and coastal defences.

Physical adaptation in the use or structure of buildings and in infrastructure

With the climate changes projected for the 2050s it is important that building uses are considered and, if appropriate, amended. For example, with rising temperatures it is inappropriate to occupy office space with increasing staff numbers or to fill computer server rooms with too much hardware without adequate ventilation and cooling mechanisms. Also, with the increased likelihood of winter flooding, the storage of materials in basements should be avoided in buildings that are located within potential flood zones. In such locations, critical machinery can also be raised above flood level, creating improved threshold levels against damage from flood waters.

Significant physical adaptation of existing building stock and infrastructure is difficult. Whilst retro-fitting is possible, it can be expensive and would usually involve a capital project. Examples of retro-fitting include increases to the capacity of sewer systems by replacing 'weak points' with larger capacity pipes or retro-fitting sustainable drainage systems to areas of land development. The Three Regions Climate Change Group's report Your Home in a Changing Climate provides more information on retro-fitting existing homes for climate change impacts. Rather than being a matter of routine course, however, opportunities for retro-fitting should be identified when extensive refurbishment or major replacement works are required to elongate the life of a building or asset.

Physical adaptation can also occur when buildings or assets are being repaired following damage. This is termed 'resilient reinstatement' and makes damage-prone assets more resilient to repeat occurrences. Examples include moving electrical sockets higher up walls above flood levels when repairing electrical systems within flood-damaged properties. This type of adaptation generally involves minimal additional costs at the time of reinstatement, but large potential long-term savings through avoidance of repeat damages.

The major opportunity for adaptation of buildings and infrastructure comes through building adaptive capacity into the design of new builds.

Buildings that would particularly benefit from this, especially in response to forecast temperature increases, include hospitals, schools, care homes and houses. Ongoing programmes of capital investment such as Building Schools for the Future provide an excellent opportunity for incorporation of appropriate adaptations. Suitable design amendments, such as adequate ventilation, shading effects through vegetation planting outside windows and the inclusion of 'cool rooms', can vastly improve the quality of life of the users of a building.

Some industry guidance presently incorporates climate change allowances in design. For example, flood and coastal defence designs make allowances for projected changes in river flows and sea levels, respectively. Adaptation allowances, covering a range of hard (e.g. structural engineering) and soft (e.g. landscaping, architectural) solutions needs to be more routinely addressed in all new-build designs.

Warnings to enable preventative actions

With increased likelihood of events such as flooding, heatwaves and wild fires, there is a need for more awareness amongst the general public so that appropriate preventative actions can be taken to avoid, or minimise, the likelihood of impacts.

Already in existence are a nation-wide Flood Warning System operated by the Environment Agency, and a Heat Health Watch system operated by the Met Office to warn the public about the risks they will face. Both of these systems are based around different levels of response, from 'awareness' to 'warning / emergency' and both enable the public to take appropriate personal action to reduce the impacts they may face from these weather events.

With some of the impacts associated with the projected climate changes, it will also be necessary to warn the public due to increasing risks or new risks that they may previously have been unaware of. Particularly relevant here is public information regarding surface water flooding, reducing the risks of wild fires during high temperatures, what to do in the event of a tick bite and the risks of drinking water from streams, for example.

Prioritisation and delivery of adaptation actions

The region needs to take a national lead in the prioritisation and delivery of adaptation actions. The present report can be used as a catalyst for this, but there remains a need for further, more detailed, determinations of:

- Which are the most critical assets to the region?
- Which assets are the most vulnerable to climate changes?
- What are the critical interconnectivities between assets and organisations?
- What needs to be addressed first?
- What are longer-term (planning-related) responses?
- Who needs to lead the adaptation activities?
- Who else needs to be involved?
- What are the timescales for adaptation delivery?

The region is already leading on prioritised and co-ordinated adaptation delivery in some key areas, for example through the projects to demonstrate adaptation proposed in the 'Climate-proofing the Cheviots' project, but this now needs to be extended more widely across the region to ensure greater resilience to the inevitable climate changes. This is a fundamental activity that needs to be led by the regional and sub-regional resilience fora.

Resource planning and management

As the climate changes, so the response from various individuals or organisations needs to change. Farmers and the emergency services are on the 'front-line' of climate change and adaptation has already been essential for financial survival and continuity of service provision, respectively. For other organisations, responses to weather-related impacts may require different approaches, use of different resource skills or numbers, or deployment of resources at different times compared to the present day.
Examples are provided below:

Approach – New pressures such as diseases, pests or invasive species will require new approaches to their management. Increasing pressures, such as wild fires in remote areas, will require specialist equipment and co-ordinated responses.

Quantity – Pest and vegetation control will be required for longer periods throughout the year as breeding and growing cycles increase; less snow clearance will be required from roads, but more pre- and post-ice gritting will be needed over the winter; sheep dipping will be required more frequently to control the spread of tick-borne disease; more debris will need clearance for culverts, trash screens, and channels as it is washed down rivers and streams during peak rainfall events.

Timing – With changing growing seasons, resources will need to be deployed for longer periods to maintain vegetation, and also changing nesting times will mean that some construction and maintenance activities will be constrained to within windows that differ from the present day.

All of these responses will require planning and management.

Increased use of novel technology and the need for further innovations

Already, there are some examples of novel approaches being applied in practice in the region. Further demonstration of the effectiveness of such approaches will help in their wider application. Also, further technological innovations will be required to help adapt to climate change. Examples of novel and innovative techniques include: demountable flood defences; sustainable drainage systems; tree-planting for shading of buildings; cool rooms in hospitals, schools and care homes; flood water storage and re-use for irrigation or livestock watering.

Influence long-term planning

Whilst some adaptation can take place in-situ with existing assets, longer-term risks from climate change can most effectively be addressed in some situations by influencing the statutory land use planning and development control process. This includes the use of existing legislation to discourage development in inappropriate locations, for example areas at risk of flooding or coastal erosion. Long-term planning can also be used to relocate assets from at-risk areas. This may involve some form of time-limited intervention in the interim, while arrangements (e.g. funding, land purchase, etc.) for longer-term relocation are pursued. This process can also be used to identify preferential locations or alignments of buildings to minimise future climate-related risks.

Long-term planning is also needed within each organisation's own medium and long-term plans, enabling any necessary changes in service provision to be highlighted well in advance.

Encourage cross-sectoral, partnership-based awareness and responses

Adaptations need to be made in each individual sector of importance to the region. Many of these will be very specific to the nature of that sector. However, it should also be recognised that through a cross-sectoral, partnership-based approach greater innovation could be delivered. This can involve delivering adaptation solutions across larger-scales than previously undertaken (e.g. whole river catchments) and can lead to 'win-win' situations.

One particular example is the storage, in key locations, of the excess rainfall that will be affecting the region by the 2050s in order to reduce flood risk. This water could then be harvested in the drier summer months for irrigation of arable land, watering of livestock or fighting wild fires in remote areas.

Crucially, cross-sectoral partnership approaches should lead to the establishment of mechanisms for sharing of resources when responding to weather events (e.g. pan-regional responses).

Lobby for change

Many of the adaptations will be undertaken (or not) within the context of existing legislation, procurement strategies, budgets and other constraints. There is a need for lobbying in an attempt to deliver adaptation approaches, as well as to make adaptation more cost-effective and easier to implement by changing the existing legislative framework.

The practical delivery of many adaptations will be constrained by existing resources, particularly financial but also equipment and personnel. With climate change, the investment in these resources will need to substantially increase if the risks are to be adequately managed. This will include greater financial resources to enable the purchase of new equipment (e.g. high-capacity pumps, boats, off-road fire fighting vehicles), employment of additional personnel (increased staff to deal with increasing and different risks) and innovation.

At the present time, many public-sector adaptations are being constrained by the rigorous adherence to defined spend profiles within each financial year, as well as 'lowest cost' versus 'most sustainable' procurement. There could be bigger advantages by accruing monies and delivering a larger-scale adaptation, rather than delivering two smaller ones in separate financial years.

It will also be important to lobby central and local government to ensure that adaptation has as much attention as mitigation in policy and legislation (e.g. inclusion in the Climate Change Bill and Local Authority Climate Change Action Plans).

Exploit the opportunities presented by climate change

Climate change brings about a number of opportunities to the region. A key component of the region-wide adaptation strategy must be to maximise the exploitation of these opportunities. The most obvious opportunities are associated with increased tourism and recreation use of the region which are likely as a result of projected rising temperatures and drier summers. There is also the need for innovation to adapt to, and mitigate for, climate change. The region's industries are well-placed to design and deliver such approaches.

Review the effectiveness of adaptation approaches and revise as necessary

As with all initiatives, it is important to regularly review progress with respect to the implementation and effectiveness of adaptation strategies across the region. If there is a need due to changing circumstances (e.g. increased rates of climate change, technological innovations) or performance issues (e.g. better or worse than expected) then a review of the lessons learned is needed and a revision of the adaptation approaches may be warranted.

WHERE NEXT?

Having read about the climate changes expected by the 2050s, their impacts on services, assets, communities, business and infrastructure across the region, and the adaptation measures that are best-suited to tackling these impacts, you may be wondering 'where next?'.

1. In response to the findings of this study there is an immediate and ongoing need for adaptation action. This ranges from planning now for future changes in the design or location of buildings or infrastructure, through co-ordinating activities and communicating knowledge across sectors, to 'on-the-ground' actions to deliver practical measures. To assist this process we have included a suggested 'Adaptation Action Plan' to cover the immediate essential adaptation activities. It is intended that this forms the basis of further dialogue, debate and, most importantly, actions across the region to start better adapting to the inevitable climate changes expected by the 2050s.

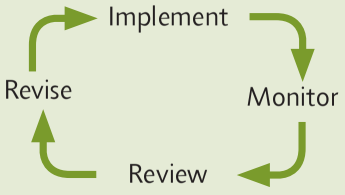
2. Beyond this, we recognise that nothing remains static. Just as the climate is changing, so the science and modelling tools used to project the climate changes are continually developing due to technological advances. Other social, economic and political factors are also evolving. For example, government policy may soon focus more strongly on adaptation, and more output will become available from existing research programmes relating to impacts and adaptation approaches. Furthermore, the 'local detail' boundaries used in this study are based on the twenty-three Local Authority districts or boroughs and these will change across large parts of the study area, resulting in new unitary authorities in Northumberland and County Durham. All of these factors mean that it would be appropriate to review and update this adaptation study at appropriate future intervals, to ensure that such changes and developments are taken into account. This will also give the opportunity to review progress with respect to the 'Adaptation Action Plan'.

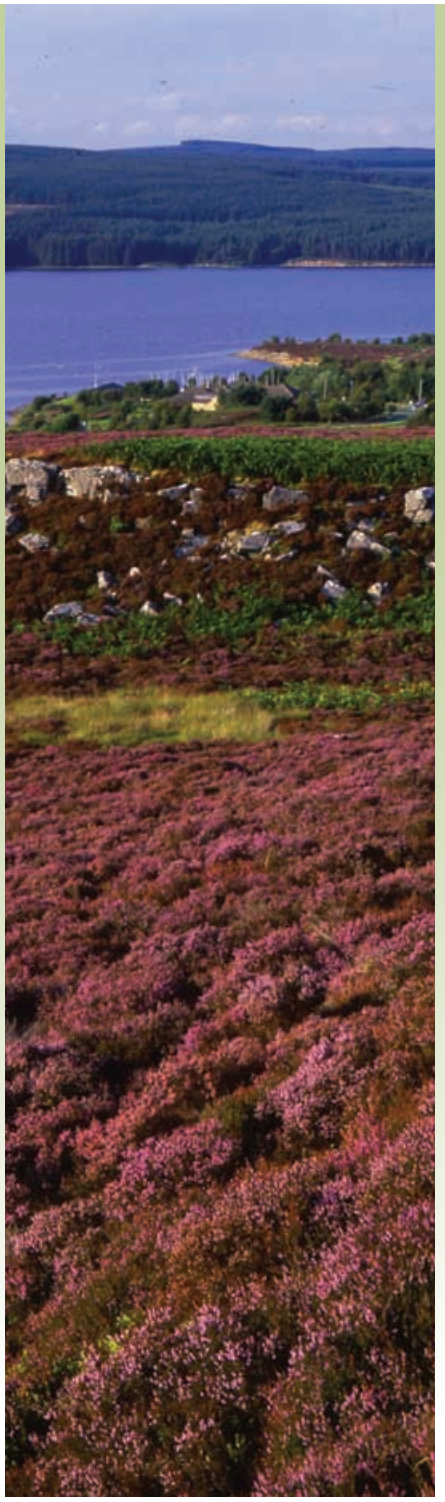
3. There is also a need to ensure that any work on adaptation is taken forward in parallel with mitigation activities within the broader agenda to tackling climate change across the region. The 'North East Climate Change Action Plan' (which is available from www.climateNE.org.uk) has a key role in ensuring both adaptation and mitigation are components of the region's approach.

4. The present study has focused on the main within-region impacts expected from projected climate changes by the 2050s. However, it is recognised that there could be changes or pressures associated with climate change from outside the region that could also directly impact upon the North East. For example, reductions in summer rainfall in the south-east, together with the scale of likely future residential development, could cause greater pressure for pan-regional water supply networks, placing increased pressure on the North East region's presently plentiful supplies. Also, with temperatures set to rise, there could be more migration to the region from elsewhere in the UK, or indeed from around the world, as other regions become excessively hot. There will also inevitably be changes to global markets that will impact on the economy of the North East. These external pressures on North East England should be considered in more detail to complement the within-region impacts addressed in this study.

High-Level Adaptation Action Summary

Reference	Adaptation Strategy	Examples	Responsibility
Adaptation 1	Gather and share information on climate change trends, impact assessments and adaptation activities across the region	• Promote regional weather data collection and analysis • Share information about impact assessments and adaptation activities via websites, conferences, etc.	• Met Office, Environment Agency, UK Climate Impacts Programme (UKCIP) • Regional: UKCIP, Sustaine, Environment Agency • Sub-regional: Northumberland Strategic Partnership, Tyne Wear Partnership, County Durham Partnership, Tees Valley Partnership
Adaptation 2	Risk awareness and risk-based management plans	• Business continuity plans • Seasonal preparedness plans • Risk assessments	• Businesses, services • Transport operators, health service, Environment Agency, public services
Adaptation 3	Inspection, monitoring and maintenance of assets	• Asset inspections and repairs • Animal welfare examinations	• Local authorities, Environment Agency, Network Rail, Highways Agency, emergency services, farmers, etc.
Adaptation 4	Physical adaptation in the use or structure of buildings and infrastructure	• Building use • Retro fitting / refurbishment / replacement • Resilient reinstatement • Capacity in new builds • Industry design guide allowances	• Local authorities, businesses, health service, transport operators, utilities providers • Research organisations (e.g. CIRIA), Government departments
Adaptation 5	Warnings to enable preventable actions	• Warning systems • Public information leaflets	• Environment Agency, Met Office, health service, national parks
Adaptation 6	Prioritisation and delivery of adaptation actions	• Risk based prioritisation • Practical delivery	• Promotion of concept: Sustaine, sub-regional Partnerships • Delivery: All

Adaptation 7	Resource planning and management	• Different approaches – new resources • Additional resources • Timing of deployment of resources	• Local authorities, transport operators, utilities providers, Environment Agency, emergency services, health service
Adaptation 8	Increased use of novel technology and the need for further innovation	• Research and development • Demonstration projects	• Universities • Business / industry • Environment Agency, local authorities, utilities providers, transport operators
Adaptation 9	Influence long-term planning	• Land use, planning and development control • Medium and long term plans	• Local authorities, Environment Agency, sub-regional partnerships, regional development agency, regional assembly • All organisations and businesses
Adaptation 10	Encourage cross-sectoral, partnership-based awareness and responses	• Shared resources • Wider-scale awareness and joint responses	• Lead: Environment Agency, local authorities, emergency services, health services, sub-regional partnerships • Involvement: All organisations and businesses
Adaptation 11	Exploit opportunities	• Tourism and recreation • Innovations	• Regional development agency, sub-regional Tourist Boards, individual businesses • Industry, businesses and universities
Adaptation 12	Lobby for change	• Central government • Local government • Organisational	• ANEC, North East Assembly, sub-regional Partnerships, Sustaine • All organisations and businesses
Adaptation 13	Review the effectiveness of adaptation approaches and revise as necessary		• Regional: Sustaine • Sub-regional: Sub-regional partnerships • Local: Each organisation and business



FURTHER INFORMATION

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