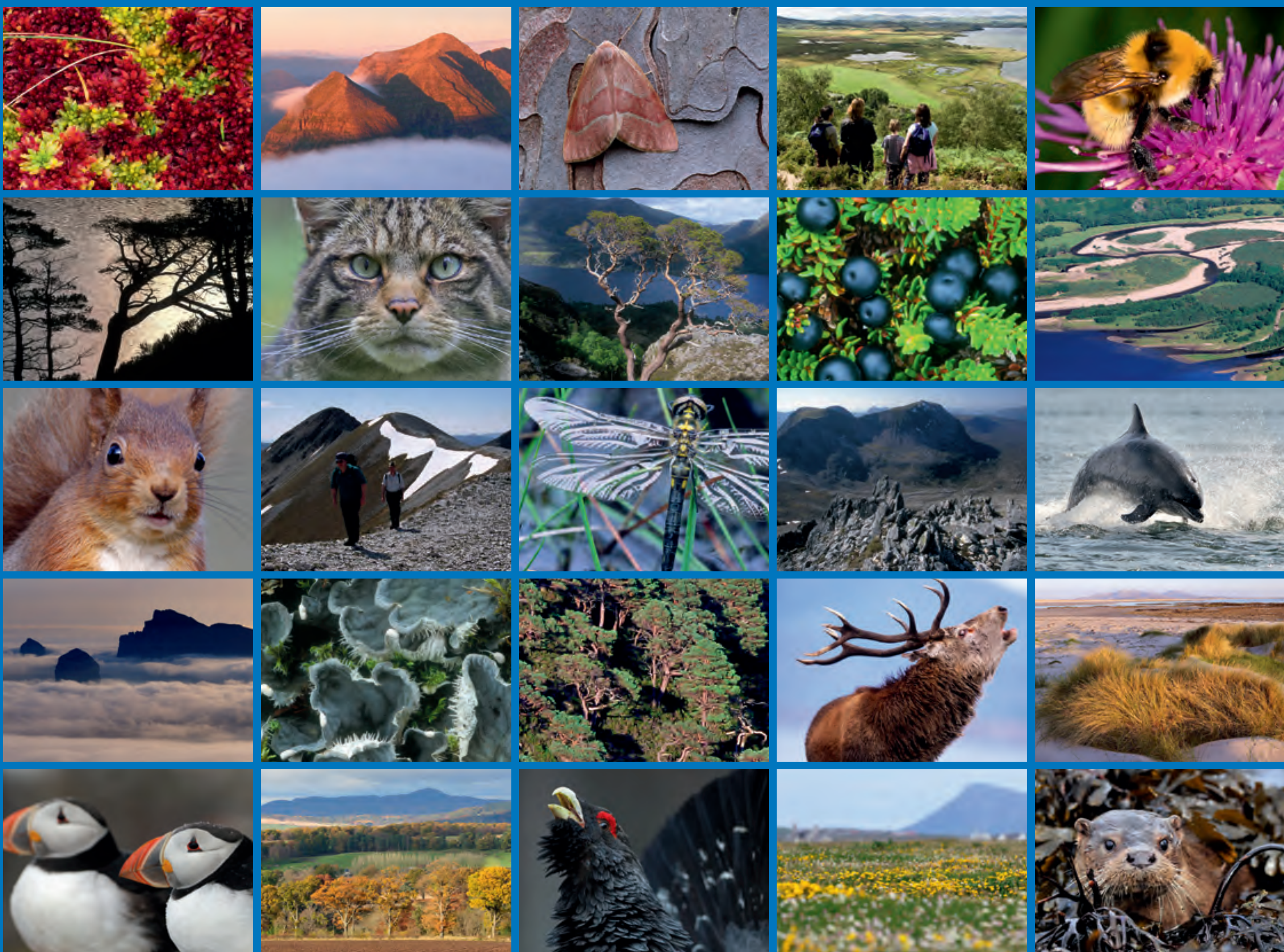
Scottish Natural Heritage
Commissioned Report No. 436

Paths and climate change - an investigation into the potential implications of climate change on the planning, design, construction and management of paths in Scotland



Scottish Natural Heritage
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COMMISSIONED REPORT

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Paths and climate change - an investigation into the potential implications of climate change on the planning, design, construction and management of paths in Scotland

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COMMISSIONED REPORT
Summary

Paths and climate change - an investigation into the potential impacts of climate change on the planning, design, construction and management of paths in Scotland

Commissioned Report No. 436 (project no. 10306)
Contractor: Walking-the-Talk
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Background

Predictions of climate change used in the research were taken from a range of models, of which the UK Climate Programme (UKCP09) is regarded as the standard for the UK. The generally accepted range of predictions from these models presents challenges and opportunities for management of paths in Scotland.

Main findings

The general trend of climate conditions towards warmer, wetter conditions will present cumulative, ongoing pressure on paths, which can be regarded as causing chronic pressure. However, the more extreme weather events that are predicted to occur will give rise to acute pressures on paths.

Acute impacts caused by distinct, extreme weather events may be highly localised and almost impossible to predict with any certainty, but are likely to cause major damage to path infrastructure. There is, however, some limited scope to adapt to, or avoid, acute impacts.

Chronic impacts may be caused by ongoing changes to the climate, such as the wetter conditions in winter, potentially resulting in gradual deterioration in path condition. Chronic impacts have the potential to affect all paths in Scotland and the effects will be seen over periods of years, and possibly decades. Some of the impacts may result from the climate itself, whereas others may be secondary impacts, such as increased path use, brought about by improved summer weather, leading to more pressure on paths.

In order to prepare for, or adapt to, climate change pressures and potential impacts a number of actions are required:

- Implementation of existing standards for construction and management of paths
- Assessment of the risks associated with climate change for each path network in Scotland
- Implementation plans to control or address the identified risks
- Adoption and funding of the plans to provide long term care for paths in Scotland to make them resilient to climate change
- Sharing of knowledge and experience of path management in challenging situations.

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1 INTRODUCTION

1.1 Background and Context

Paths play an important part in providing people with opportunities for enjoying the outdoors, for physical activity and for active travel throughout Scotland. Significant investment has been made in recent years to provide high quality paths across Scotland to encourage more active lifestyles and in response to recreational pressure and demand. This has included a wide range of activities from developing networks of paths close to where people live through to large-scale repairs of upland paths. Much of the work has been publicly funded, and has been implemented by public, private and voluntary sector organisations. Alongside this has been the development and promotion of good practice in path construction and management.

The issue of climate change has, at the time of writing (March 2011), a high public profile and there is wide debate about the nature and scale of the potential impacts. The Scottish Parliament approved the Climate Change (Scotland) Act in 2009. Part 4 of this Act, which came into force in January 2011, places duties on public bodies which include developing strategies for adaptation to climate change. The Scottish Government is developing a Climate Change Adaptation Framework, which outlines the issues and actions necessary across society that will be needed to prepare for the potential impacts of climate change. Specifically, with respect to enjoying the outdoors it states:

> "Climate change will have significant implications for people's interaction with the natural environment. Key developments include the increasing rate and scale of landscape change; new patterns of recreation and tourism, both locally and nationally, new approach to the design and planning of settlements, with an enhanced role for green infrastructure. These developments have important implications for people's enjoyment and use of the natural heritage and, if managed effectively, support better health and wellbeing and will contribute to the economy." (Scottish Government, 2009)

Scottish Natural Heritage (SNH) has a policy statement and action plan for climate change, which provides a context for this study (see Climate Change and the Natural Heritage):

> "SNH views climate change as the most serious threat over coming decades to Scotland's natural heritage. In addition to its environmental consequences, climate change is likely to have major social and economic implications for people in Scotland and elsewhere. SNH aims to understand the effects of climate change on the natural heritage, and to help deliver the contribution that the natural heritage can make in limiting it and adapting to it." (SNH, 2009)

SNH's 'paths statement' (see Paths - linking people, places and nature) recognises that, as the impacts of climate change become more evident, new challenges in the planning, design, construction and maintenance of paths will need to be addressed.

SNH commissioned this research study to investigate climate change trends affecting paths and suggest adaptations in practice. The objectives were to consider the adjustments necessary to the management of the current infrastructure and changes to good practice for new provision and upgrading of paths. This work aims to provide an overview of the topic, relevant to paths, and to identify and raise awareness of changes required by the access profession and paths industry to climate change.

1.2 Climate change predictions

There is a generally accepted view that increased levels of CO_2 (carbon dioxide) and other greenhouse gases in the atmosphere are leading to an increase in global mean temperature and changes in atmospheric activity that will lead to changes in both climate and weather. The most authoritative predictions for the UK are provided by the models within the United Kingdom Climate Projections (UKCP09) website (http://ukclimateprojections.defra.gov.uk). These models have been used as a basis for institutional actions to mitigate and prepare for the possible impacts of climate change and are embedded in Scottish Government policy.

1.2.1 Climate change models used in this study

UKCP09 gives projections for three of the scenarios from the International Panel on Climate Change's (IPCC) Special Report on Emissions Scenarios. Each of these emissions scenarios represents a different pathway of economic and social change over the course of the 21st Century. Projections of climate change that have been produced by UKCP09 represent a range of possible conditions because they have to take into account uncertainty due to natural variability as well as shortcomings in our current understanding and representation of the Earth's climate system. Within each emissions scenario the range of possible outcomes is presented as a set of probabilities, which define the likelihood of the predicted changes occurring.

For the purposes of this report we have presented the range of projections across the three emissions scenarios in an attempt to simplify the amount of data that could be presented. These range from a Lower Limit, taken from the low emissions scenario at 10% probability (i.e. change is unlikely to be less than this lower limit); to an Upper Limit, taken from the high emissions scenario at 90% probability (i.e. change is unlikely to be more than this upper limit). We have also used a Central Estimate derived from the medium emissions scenario at 50% probability.

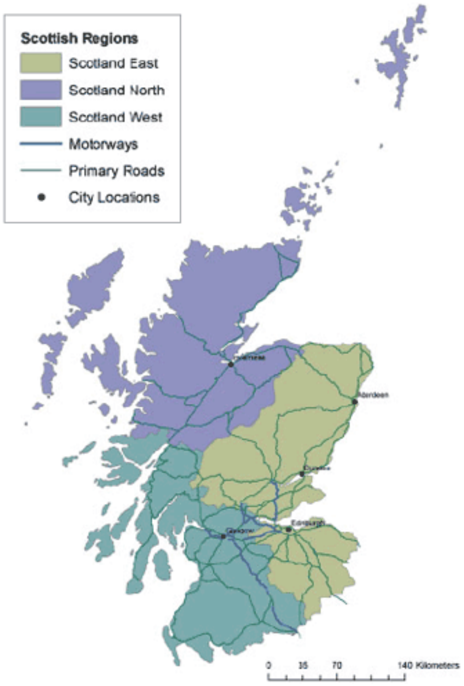
The projections used in this study were for the 30 year period centred on the 2050s (2040-2069), on the assumption that this offers a reasonable time horizon for decisions about path design, construction and maintenance. The projected paths for the three emissions scenarios – low, medium and high - are similar up to around the 2050s, and then start to diverge so there is a more noticeable difference between the three emissions scenarios by the 2080. The relationship between projections is summarised in Table 1.

Table 1: The relationship between emissions scenarios and predicted changes

Emission scenario	**Predicted change by the 2050s**		
	10% probability	**50% probability**	**90% probability**
High			Upper limit
Medium		Central Estimate	
Low	Lower limit		

The UKCP09 models generally provide outputs aggregated to a 25km grid square level. It is also possible to obtain some data aggregated to 'climatic regions' (North, East and West Scotland as shown in Figure 1) or to river basins. Changes are referenced to the mean of climatic variables over the period 1961 to 1990 to allow comparison with current situations.

Figure 1: Map showing Scottish regions (from SNIFFER, 2006)



1.2.2 Specific weather events or conditions critical to paths and recreation

In addition to considering the climate, it is important to look at the variability of weather that contributes to the mean climatic conditions. There are particular weather events that are likely to be significant for path management and recreational use. These include:

- intense rainfall events/wet days
- air frost/freeze thaw events
- prolonged dry spells
- heat waves
- cold waves
- snow cover
- storms (which include high winds)
- storm surges and sea level changes

The climate projections are unable to provide any insight into these weather events and it is necessary to use the UKCP09 'Weather generator'. Some weather events (such as the wettest day) have been modelled across Scotland using the Weather Generator, allowing maps to be produced, whereas other variables (such as intense rainfall) needed to be calculated. The Weather Generator is able to simulate weather conditions daily or hourly for any 5km grid square and emissions scenario. The output of these simulations can then be further analysed to identify the occurrence of particular weather events using the Threshold Detector routine within the software. These simulations generate large volumes of data, so for practical purposes, five grid squares were selected from locations across Scotland and weather generator runs produced for the high and low emissions scenarios. The locations were selected to give national coverage, and also to relate to sites where feedback had been given by path managers. The chosen locations were:

- Kinlochewe, Wester Ross.
- Loch Lomond
- Glentrool, Dumfries and Galloway
- Aboyne, Aberdeenshire
- Dunbar, East Lothian

UKCP09 models cannot provide data regarding snow cover, so an alternative source is quoted for these (Harrison *et al*, 2001).

1.2.3 Predicted changes to climate and extreme weather events.

Unfortunately it is not possible to present all data in a single format such as a map because the outputs for different climate and weather variables from the UKCP09 projections and the Weather Generator are not compatible, or available to the same resolution or coverage. Therefore the predicted changes are illustrated though a mixture of maps and tables for regions and specific locations.

1.2.3.1 Temperature and precipitation

Predictions of temperature and precipitation are provided for the three Scottish 'climatic regions' (North, East and West Scotland), to provide a general picture of potential change. The figures are derived from UKCP09, based on the emission scenarios and probabilities set out in Table 1. Table 2 to Table 4 demonstrate that there is some regional variability within Scotland for these major climate variables, although these do not vary sufficiently to require different adaptation strategies across Scotland.

There is an overall increase in mean summer temperatures in all projections as shown in Table 2, and the same applies to winter (Table 3). The predicted increase in mean winter temperatures may result in more precipitation falling as rain rather than snow, and it is likely that this increase will also raise the altitude of the freezing point.

Table 2: Predicted increases to summer temperatures by 2050s

	Mean Summer Temperature (°C)			Summer Maximum temperature (°C)		
	Lower limit	Central estimate	Upper limit	Lower limit	Central estimate	Upper limit
North Scotland	+0.9	+2	+3.9	+0.9	+2.5	+5.3
East Scotland	+1	+2.3	+4.5	+1.1	+3	+6.4
West Scotland	+1	+2.4	+4.4	+0.9	+3	+5.9

Table 3: Predicted increases to winter temperatures by 2050s

	Mean Winter temperature (°C)			Winter minimum temperature (°C)		
	Lower limit	Central estimate	Upper limit	Lower limit	Central estimate	Upper limit
North Scotland	+0.6	+1.7	+3	+0.6	+2	+3.7
East Scotland	+0.6	+1.7	+3.1	+0.6	+2	+3.8
West Scotland	+0.8	+1.9	+3.3	+0.9	+2.4	+4.3

Table 4 shows that winter precipitation is predicted to increase in most situations. Western Scotland is predicted to see the highest increase. Summer rainfall is more likely to decrease but there is less regional variation in these predictions.

Table 4: Predicted changes to precipitation by 2050s

	Winter mean precipitation (%)			Summer mean precipitation (%)		
	Lower limit	Central estimate	Upper limit	Lower limit	Central estimate	Upper limit
North Scotland	-1	+13	+26	-20	-10	+3
East Scotland	+2	+10	+20	-26	-12	+2
West Scotland	-1	+15	+31	-25	-12	+2

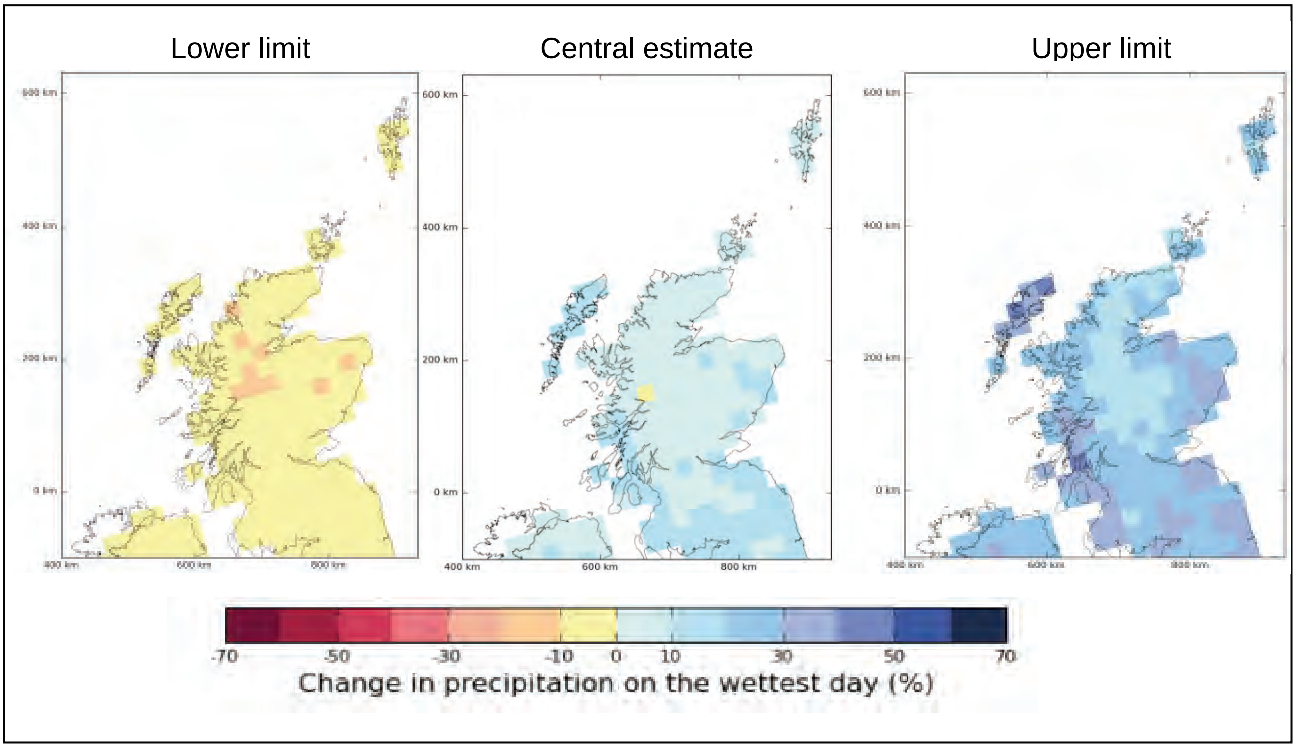
Temperature changes will have an effect on the growing season, and UKCP02 predicts that by the 2050s the growing season may start between one and three weeks earlier, and finish up to three weeks later, representing up to six weeks additional growing time per annum (SNIFFER, 2006). The UKCP02 data suggests that the difference will be greatest in the West, although observed records have shown the East benefitting from longer growing seasons since 1961 (SNIFFER, 2006).

The UKCP09 models are unable to detect significant changes to dry spells or heat waves / cold waves, which would be associated with anticyclone-dominated weather patterns. This is mainly relates to the uncertainty in the models rather than indicating that there will be no change.

1.2.3.2 Precipitation intensity

Predictions of precipitation intensity can help to identify whether there is an increased risk of flooding from climate change. The maps in Figure 2 show that there is less than ±10% change in the wettest day in winter across most of the country under the lower limit and central estimate predictions. In the maximum prediction there could be 30-40% increase in rainfall / precipitation on the wettest day in winter for coastal areas of Scotland. The upper limit change prediction would have serious implications for managing surface water on paths and existing drainage may struggle to handle the run-off during these periods, particularly if water levels are already high.

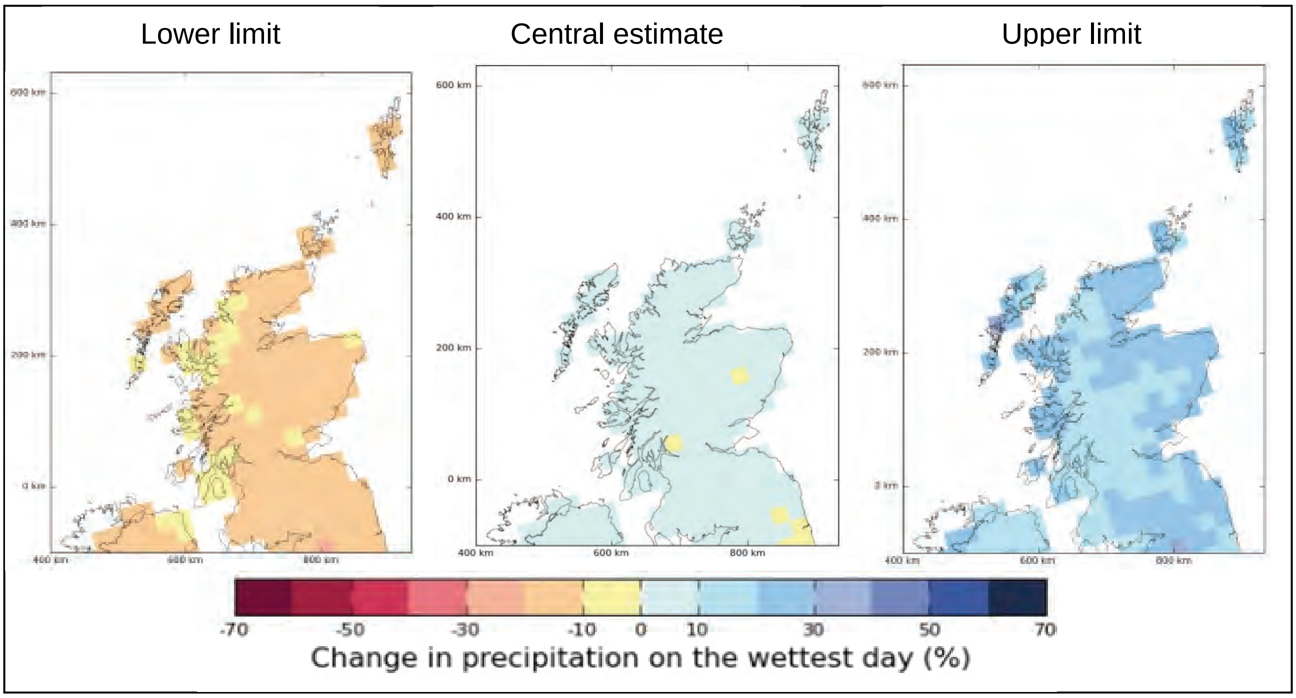
Figure 2: predictions of wettest day in winter (2050)



source: ukclimatepredictions website – generated using UKCP09 data

The maps in Figure 3 show that the wettest summer day could range from 10-20% less in the lower limit change prediction through to 10-20% more in the upper limit change prediction.

Figure 3: predictions of wettest day in summer (2050)



source: ukclimatepredictions website – generated using UKCP09 data

As it is not possible to use the available climate data to predict changes in intense rainfall events, the Weather Generator was used to estimate the incidence of intense rainfall events at the five selected locations. The threshold for these events was set at more than 30mm of rain in 24 hours in the 30 year period centred on 2050, with the results shown in Table 5. In general, intense rainfall events are more frequent for the higher emissions scenario, especially for the sites in the West, with the biggest effects in autumn and winter. Extreme events are also more likely further north.

Table 5: Weather Generator simulations of number of days with >30mm precipitation for 5km squares in 2050s

Site		Winter (Dec-Feb)	Spring (Mar-May)	Summer (Jun-Aug)	Autumn (Sep-Nov)
Aboyne	Baseline (1961-90)	0.3	0.2	0.1	0.5
	Unlikely to be less than	0.1	0	0	0.1
	Unlikely to be more than	0.9	0.8	0.6	1.2
Dunbar	Current baseline	0.1	0.1	0.3	0.3
	Unlikely to be less than	0	0	0	0.1
	Unlikely to be more than	0.5	0.4	0.6	0.8
Kinlochewe	baseline	4.1	1.9	0.5	3.5
	Unlikely to be less than	2.4	1.3	0.3	2
	Unlikely to be more than	7.8	4.1	1.3	8.1
Loch Lomond	baseline	1.3	0.6	0.4	1.4
	Unlikely to be less than	0.9	0.2	0	0.6
	Unlikely to be more than	3.5	1.4	1.3	3.7
Glentrool	baseline	0.9	0.5	0.2	1.3
	Unlikely to be less than	0.5	0.1	0	0.7
	Unlikely to be more than	2.3	1.2	0.9	3.3

1.2.3.3 Freeze-thaw cycles

The precise relationship between weather and frost erosion is complex but, as an approximation, it appears that damage to paths is related to the number of freeze-thaw cycles suffered. An arbitrary threshold of 3 successive days with mean daily temperature less than 0°C was used to investigate the incidence of these cycles at the five sample sites. In all cases, under both high and low emissions scenarios, the number of cycles around the 2050 period was less than is currently experienced.

It appears that climate change may reduce the incidence of damage from freeze-thaw action at low altitude. However, the Weather Generator data does not take account of altitude, so the uplands may actually experience more frequent cycling of temperature around freezing where previously the ground was frozen for extended periods. This effect may also be complicated by changes in snow cover.

1.2.3.4 Snow cover

The Climate Trends Handbook (SNIFFER, 2006) provides a useful summary of how snow cover has changed since 1961, and gives predictions based on the UKCP02 models. This has not been updated for the new climate models.

The Handbook states that the number of days of snow cover has reduced in each region and in all seasons over the period 1961 – 2004, and that the 'snow season' is getting shorter (i.e. reduced snow cover in autumn and spring). The western Highlands shows the greatest reduction (in days) of snow cover but in northern mainland Scotland there has been an increase.

However, in terms of future predictions the climate models do not provide a useful basis for snow cover – only the amount of precipitation. Therefore estimates of snow cover are taken from The Scottish Executive Central Research Unit (Harrison *et al*, 2001). Their emissions scenarios are not exactly consistent with the UKCP09 models, but the estimates for Scotland as a whole suggest a decrease of between 7 days (approximately equivalent to the lower limit) and 19 days (approximately the upper limit) in snow cover by the 2050s. They also give more detailed predictions for different regions of Scotland, and Table 6 represents an approximation of the central estimate (mean of the medium low and medium high scenarios used in Harrison *et al*, 2001).

Table 6: Estimated change in snow cover by 2050s for approximately central estimate predictions

Region	Mean snow cover 1961-1990 (number of days)	Predicted snow cover by 2050s (number of days)	Reduction
Highland	53	37	30%
Grampian	45	30	33%
Tayside	51	36.5	28%
Strathclyde	30	18	40%
Central	39	26	33%
Fife	19	9.5	50%
Lothian	26	14.5	44%
Borders	37	23.5	36%
Dumfries & Galloway	22	12.5	43%

1.2.3.5 Storm surges and sea level rise

There is a change in the predictions made between the UKCP02 and UKCP09 models relating to the frequency and intensity of storms. The newer model no longer predicts a change in frequency or intensity compared with baseline records – the new model recognises that there may be variability in the frequency of storms but it is not statistically robust to predict a change. Earlier research by SNH for the Scottish Executive (Dawson *et al*, 2001) suggested that there would also be a marked increase in storm surge levels in some parts of Scotland, by up to 3.5m. However, more recent evaluations have asserted that these estimates are not statistically significant and that storm surge levels are likely to be no higher than currently experienced.

Recently published literature (Rennie and Hansom, 2011) suggests that isostatic uplift, where there is a relative change in sea-level as a consequence of the last ice-age, is unlikely to outpace global sea level rise. This research also shows that sea level predictions using the High Emissions Scenario most closely match observed tidal records. This suggests that coupled with storm surges, even with no change in frequency or intensity, predicted changes to climate will have a negative impact on the coastline in Scotland.

1.3 Summary of climate change predictions relevant to paths

1.3.1 Milder, wetter winters.

The **average temperatures** in winter are predicted to be higher and there is likely to be an **overall increase in winter precipitation**. An increase in **freeze/thaw events** may occur at higher altitudes and **decreased snow and ice cover** are predicted.

1.3.2 Warmer, drier summers

The **average temperatures** are predicted to be higher, along with the **maximum summer temperature** and the number of very hot days. **Less summer rainfall** is also predicted in most circumstances. The growing season is predicted to extend, by up to three weeks at both ends of the season.

1.3.3 Extreme rainfall events

Extreme rainfall events are predicted to be **more frequent and more intense**, particularly in western Scotland.

1.3.4 Storms and sea level rise

Although the frequency and intensity of storms is not predicted to increase, coastal areas are predicted to be **more at risk of flooding and storm damage as a result of sea level rise**.

There is uncertainty regarding the extent and magnitude of these predicted effects, which is determined by the range of possibilities in the climate change models. Further information is available in the summary: Scotland's Climate Change Adaptation Framework - how our climate is changing.

2 POTENTIAL IMPACTS ON PATH FEATURES

There are two main types of pressure on paths that are likely to occur as a result of climate change. The general trend of climate conditions towards warmer, wetter conditions will present cumulative, ongoing changes, which can be regarded as **chronic pressure**. However, more extreme weather events are also predicted to occur, and these will give rise to **acute pressure**.

The severity of the impacts that results from these pressures is partly dependent on the quality of the path construction and partly on the management regime. **Chronic impacts** have the potential to be widespread and the pressure is predictable. **Acute impacts**, however, tend to be more localised because they are associated with specific events, which makes them very difficult to predict for a given location.

2.1 Potential impacts of predicted climate / weather patterns

Wetter winters will increase the amount of surface flow which will lead to greater erosive force of water on drainage ditches and path surfaces. Whilst this increase is predicted to be most marked in the north-west, existing routes and path surfaces in this area may already be designed to cope with current high rainfall.

Saturated soils will result in water-logging of some path surfaces and consequent trampling damage, though by-passing and path-edge erosion may be better contained. The most severe and acute damage is likely to occur from adjacent ground slumping onto a path or taking the path with it. Areas most at risk from land slips and slumps are those with ‘weak’ soils, those that are high in clay content.

Warmer winters will lead to less snow cover and may result in more frequent freeze-thaw events at higher altitudes. It will potentially make path management a more viable winter occupation as paths will not be covered in snow or bound by ice. Warmer temperatures may also make outdoor recreation a more attractive proposition for a wider range of visitors.

Decreased snow and ice cover in the uplands will reduce the protective insulation that binds the soil and vegetation during the winter months, exposing them to trampling and scouring by water. This chronic effect will have significant consequences for path condition and management. Although in winter off-path damage is reduced or prevented by snow cover, predicted decreases, potentially allow more widespread damage to habitats where people stray away from defined path lines. Reduced snow cover may also encourage more people to take to the hills who might otherwise be put off by their lack of the specialist skills and equipment required in winter conditions.

If an increase in **freeze/thaw events** occurs at higher altitudes, these would loosen path surfaces, steep ditch edges and adjacent, bare ground. Where sudden thaws of snow take place, or where the ground beneath snow is unfrozen there is potential for more acute impacts to occur, as the meltwater can scour surfaces that may otherwise have been protected by ice. However, stonework should not be affected if it is properly constructed and maintained.

Longer growing seasons will mean that vegetation growth may be more vigorous. In upland areas this may help with vegetation restoration, while lowland paths will potentially require more frequent vegetation management.

Hot, dry summers can lead to the break-up of path surfaces with a consequent blowing away of the fines in windy weather. This problem is largely restricted to schistose soils. Hot, dry weather will weaken plant growth and threaten re-vegetation works in upland settings. It will also make path work more exhausting and could prejudice worker safety. Drier and warmer summers may have a positive impact on demand for recreation and may change the patterns of use.

Intense rainfall has the potential to cause acute impacts in all path settings. It will increase the scour on path surfaces and can lead to large-scale wash-out. It also increases the demands and pressure on drainage features - ditches can be eroded by the sheer force of water and drains will be unable to cope. Revetments may be undermined and collapse and bridges will be washed over and may even be washed away. Such events have the potential to be a danger to both recreational users and path workers who may have return routes suddenly swamped and unsafe for passage.

Storm force winds associated with extreme weather events may cause acute damage to path infrastructure but more importantly, woodland paths may be seriously damaged through windthrow.

2.2 Potential impacts on lowland path settings

2.2.1 Coastal paths

It is likely that the greatest impacts on coastal paths will be acute, resulting from storm surges, but there are also likely to be chronic impacts associated with coastal erosion through sea level rise. Where there is inadequate protection against incursion by the sea (e.g. rip-rap, sea walls or other built defences) it is likely that damage will be extensive during extreme events. Paths on low-lying coastal areas may therefore become more susceptible to damage with the predicted sea-level rise, particularly where this is compounded by storms and storm surges.

2.2.2 Riverside paths

The main risk to riverside paths comes from elevated water levels and increased erosion of river banks, caused by intense rainfall events and/or wetter winters. In some places flood debris could cause physical damage to the path surface through saltation (bouncing of particles suspended in the water) and, as flood waters recede, there may be deposition of mud and silt across the path. Paths constructed on flood plains may lie on unconsolidated alluvial material which is susceptible to extensive damage during extreme flood events. This means that even highly specified paths could be compromised if a river channel-hops during a spate.

As well as the potential for inundation of the path, bridges are likely to be at higher risk of damage from flooding and flood debris (particularly where upstream land use could result in large objects such as brash or windblown trees in being washed downstream).

2.2.3 Urban paths

Paths that have been constructed for active travel (e.g. cycle commuting) or with all-abilities specifications may be more difficult to maintain as a result of intense rainfall events which may impact on surfacing and drainage. Well-constructed and maintained sealed surfaces are likely to be less affected by the effects of climate change than unbound surfaces, except in extreme conditions that cause widespread or deep erosion sufficient to undermine the whole path. Poorly constructed or weak worn sealed path surfaces may show similar effects to unbound surfaces.

2.2.4 Rural paths

If growing seasons extend as a result of milder and wetter winters there is likely to be a need to increase the amount of vegetation management on some paths and some natural surfaced paths may deteriorate if soils are more persistently saturated in the winter. There may be a need for drainage to be included at a higher specification to cope with greater precipitation although it is probably not feasible to provide capacity for the worst-case intensive rainfall.

Similar to urban situations, paths that have been designed for active travel or all-abilities may be more difficult to maintain within expected standards, particularly where unbound surfaces are used.

2.3 Potential impacts on upland paths

Some upland path managers who were interviewed as part of the study are already routinely adapting path designs and specifications to take account of the more chronic effects encountered in the uplands, and this may have influenced their opinions of potential impacts of climate change. Building higher and drier may be becoming more commonplace, allied to more robust specification. Greater emphasis needs to be placed on the importance of an effective maintenance regime for upland paths. Whilst users are more tolerant of a wide range of path conditions in the uplands, there is a strong lobby seeking to ensure that path works are sensitive to the landscape setting, which may restrict options for more heavily engineered paths.

2.4 Summary of potential impacts

To summarise these impacts the following tables present the component parts of paths and path networks compared with a ‘generic’ outlook of the predicted climate to highlight potential negative impacts as well as positive changes. A scoring system indicates the likely severity of any subsequent impact, with explanatory notes for further interpretation of the tables.

Table 7: Potential impacts on Lowland Paths

		Drainage	Surfaces: Natural	Surfaces: Unbound	Surfaces: Sealed	Engineering features	Bridges	Vegetation management	Adjacent Ground	Path management Staff	Recreational Users	Access-ibility
Chronic Impacts	Wetter winters	X	XX	X	~	X	X	X [1]	X	X	X	*X*
	Milder winters	~	~	~	~	~	~	X [1]	~	+	+	~
	Saturated Soils	X	XX	X	~	XX	~	XX [1]	XXX [2]	X	~	*XX*
	Longer growing season	X	~	~	~	~	~	[1]	~			
	Warmer, drier summers	~	~	X [3]	X [4]	~	~	~	~	?	+	+
Acute Impacts	Intense rainfall	XX [6]	XXX	XX (X) [5]	X (XX) [5]	XX	XXX	X	XX [6]	X	X	*XXX*
	More high winds	~	~	X [3]		?	~	~	XXX [7]	X	X	*X*
	Storm surges [8]	XXX	XXX	XXX	XXX	XXX	XXX	?	XXX	XX	XX	*XXX*

Notes: X has a negative impact (degree of negativity is implied by the number of Xs), + has a positive impact and ~ is neutral; ? is uncertain due to variability in features / path settings

[1] Warmer and damper conditions extend the growing season and encourage more growth but saturated soils make it difficult to gain access with machines for cutting
[2] Saturated soils, caused by a combination of warmer winters and increased rainfall, can cause major land slippage
[3] Long dry spells can lead to the break-up of unbound path surfaces, with high winds subsequently blowing out the fines
[4] High temperatures lead to premature ageing of bituminous surfaces (e.g. cracking), and can cause softening (>45°C surface temperature)
[5] Dependent on location (riverside paths are likely to suffer from the effects of flash flooding) sealed surfaces appear to fare better
[6] Paths with adjacent land use that is not 'sympathetic' to path management (e.g. surface water from roads, or land drainage for agriculture) are likely to be impacted more severely than where paths are 'integrated' into the land management regime.
[7] Woodland storm damage
[8] Storm surges have the potential to have wide ranging and catastrophic impacts on coastal paths and associated infrastructure

Table 8: Potential impacts on Upland Paths

		Drainage	Surfaces: Natural	Surfaces: Unbound	Stonework	Bridges	Revegetation [1]	Adjacent Ground	Path Management Staff	Recreational Users	Accessibility
Chronic Impacts	Wetter winters	X	XX	X	X	X	+	~	X	~	X
	Saturated Soils	X	XX	X	~	~	~	XXX [2]	X	~	X
	Milder winters	~	~	~	~	~	+	~	+	+	+
	Decreased snow/frozen ground	-	XX	XX	-	-	+	X	+	++	-
	More freeze/thaw	XX [3]	XX	X	X	~	X	X [3]	~	~	-
	Warmer, drier summers	~	~	X [4]	~	~	XX	~	?	+	+
Acute	Intense rainfall	XX	XXX	XX	XX	XXX	X	X	X	X	-
	More high winds	~	~	X [4]	~	~	~	~	X	X	X

Notes: X has a negative impact, + has a positive impact and ~ is neutral; degree of negativity is implied by the number of Xs

[1] Warmer and damper conditions encourage the growth of transplanted turf and seedlings and extend the growing season but drought has a contrary effect and freeze/thaw can lift vegetation and intense rain may wash it out
[2] Saturated soils, caused by a combination of warmer winters and increased rain fall, can cause major land slippage
[3] Freeze/thaw lifts bare soil, a particular issue on exposed ditch sides or other bare ground
[4] Long dry spells can lead to the break-up of path surfaces, with high winds subsequently blowing out the fines

2.5 External influences that may exacerbate impacts of climate change

In parallel with the direct challenges and opportunities of climate change, a number of external influences could conspire to change conditions for path management. There may be additional pressures on land use to ensure food security, or changes to recreation patterns leading to different requirements or expectations.

2.5.1 Land Use

Adjacent land uses can have a direct bearing on path management. Competition for space can lead to paths being marginalised and sited on less favourable ground that may be prone to flooding or storm surges. Adjacent land uses may see a path as convenient shedding ground for their drainage problems.

Land management operations distant from a path can have direct consequences for a path in extreme weather. For example, forestry brash can be washed downstream damming against a bridge and leading to its destruction. Large scale drainage schemes can also have a dramatic effect on hitherto small burns, changing bridge requirements for paths that cross the burn.

Grazing regimes affect the vegetation adjacent to a path and the presence of livestock (particularly cattle) can have a negative impact on path features such as drainage. On the other hand there are recent examples of a reduction in grazing pressure leading to a flush of scrub and woodland regeneration, which is able to absorb more rain and stabilise soils on slopes.

Climate change may have an influence on surrounding land use policy and practice. As conditions change outwith Scotland, there may be additional pressure to optimise the production from agricultural land. There may be pressure to make more use of Scotland's water resources for the benefit of other parts of the UK with consequent increased fluctuations in water level in lochs and rivers. There will continue to be pressure for more wind farms in the uplands with possible consequences for drainage and down-stream water flows.

There will probably be a longer growing season and one that extends higher up the hills, which may encourage more development of woodland (both native and commercial species). This may provide additional recreation opportunities and/or help to stabilise slopes.

2.5.2 Changes to recreational patterns and activities

The predicted changes to the Scottish climate are likely to give rise to more favourable conditions for path use in most settings. It is possible that warmer, drier summers will encourage more people to use paths, and/or for people to use paths more frequently. Milder winters may also contribute to increased use of paths.

External factors, such as increased pressure to find reduced or carbon-free transport options, may also influence use of paths. This will potentially change demand on routes that connect settlements or can be used for active travel functions. Additionally there may be enhanced promotion of healthy lifestyles or changes in recreational 'fashions'.

In the uplands it seems that a plateau has been reached in Munro bagging and other walking activity. On the other hand, there appears to have been a recent upsurge in mountain biking and 'challenge events' continue to increase, with the potential to initiate further erosion.

3 EXPERIENCE OF DEALING WITH EXTREME WEATHER EVENTS

In developing understanding of the potential impacts of, and possible responses to, climate change, investigations were made into existing experience and practice among path managers. The focus of this aspect of the research was to find examples of extreme weather events and their respective impacts that might be equivalent to those predicted by climate change, and to investigate the approaches taken to dealing with the impacts.

Views were sought from practitioners representing different locations (upland, coastal, rivers, loch sides and urban) from different geographic areas across Scotland. Some 20 respondents contributed their experience; they included 6 access officers, 4 site managers and representatives of the NGO, national park and national agency sectors. A good geographic spread was achieved with low ground path managers right across the Central Belt, 2 low ground practitioners from the Highlands, and upland path managers from the North West Highlands, the Cairngorms and the Southern Highlands. Information was gathered via:

- On-line survey and email questionnaire – 12 completed
- One to one phone interviews – 12 carried out
- A workshop -14 attendees
- A site visit with the Upland Path Advisory Group

The outcomes of the workshop are given in Appendix 1 and a summary of experiences are highlighted in section 3.1 below.

In broad terms path managers could readily recall incidents of damage to paths that could be attributed to more extreme weather events. Many of these are recent events, such as paths being undermined or over-washed by storm surges and bridges being washed away after extreme flooding, but some events were recalled from longer ago.

However, there are very few path managers with sufficiently long service to be able to provide a view on the frequency of return of extreme events. This means that it is not possible to draw conclusions from the responses as to whether there has been a measurable change in extreme weather events affecting paths, or if these events represent the ‘expected’ variation in weather patterns. For the purposes of assessing potential responses to climate change, it has been assumed that these reported events are typical of the predicted changes that could become more widespread and/or frequent under climate change scenarios, rather than being evidence of climate change impacts.

Managers confirmed that a clear distinction can be drawn between upland and lowland paths, and this report has largely separated out analysis and recommendations between these two locations. Upland paths are usually managed primarily to counter erosion and restore damaged landscapes, i.e. for conservation purposes; lowland paths are managed primarily to enhance and facilitate recreational opportunities. Upland path users are generally prepared to encounter harsh weather and less than ideal path conditions; lowland paths encourage a wider spectrum of users with higher expectations of path quality.

There may be higher landscape sensitivities in the uplands (a pressure not to over-engineer path solutions) compared with many lowland path settings. Upland paths are generally constructed to cope with more extreme conditions and may therefore be better able to cope with climate change and as a result it is possible that better transfer of experience and practice from the uplands would be beneficial for lowland paths.

3.1 Examples of impacts of extreme weather event in different path settings

The direct experiences of path managers across a range of locations and weather conditions included:

3.1.1 Upland Paths

Snow melt followed by heavy summer rain: this has led to surface scouring on Lochnagar, Deeside. It resulted from a combination of factors and may be typical of likely future impacts in the uplands: abrupt melting of unconsolidated snow during the winter months followed by heavy downpours during the summer eroded path surfaces not designed or constructed to cope with these levels of attrition. This case was reported from the heart of the Cairngorms where a protective cover of snow and ice might have been expected.

Snow melt and heavy rain on unfrozen ground: this has led to undercutting of pitching and drainage features as well as surface scouring on Beinn Alligin, Torridon, in the north west Highlands, where paths and stalkers routes have traditionally been constructed to cope with high rainfall events.

Summer drought and high winds: this has led to loss of fine surface material on Ben Lomond. It is a problem most often associated with the schist-derived glacial tills of the southern Highlands where surfaces are constructed from locally-won material that is very fine in nature. This surface can be literally blown away in dry and windy summers exposing the stony aggregate beneath, making the walking surface uncomfortable and forcing people off-path. This can occur at any altitude including remote high tops where maintenance is a challenge.

Torrential rain: this has led to wide-scale erosion and scarring both on and off the path in Scarth Gap, Buttermere, Cumbria. An unprecedented head of water built up causing a 100 metre gully on a traditional “pack-horse” route that, it is estimated, will cost £50,000 to repair.

Extreme rainfall event: around 75mm of rain fell over a 24 hour period in July 1985, including around 40mm within half an hour in Beinn Ghlas in the Ben Lawers range. In the 1960s and 70s the route up the flank of the mountain had been re-aligned twice, mostly to avoid damage to important flushes. Prior to this monsoon-like downpour, there were small ruts within the vegetation but the vegetation remained intact; afterwards these ruts had deepened through the protective mat, exposing the mineral soil and leading to rapid erosion thereafter. Over time, the erosion scar widened as walkers avoided the ruts.

3.1.2 Coastal Paths

Tidal / storm surges: these conditions result from combination of high winds and tides. Winds from an unusual direction led to under-cutting and wash-out on sections of the Fife Coastal Path. Storm surges have also affected the John Muir Way, East Lothian and John O’Groats coastal path, suggesting that it can occur at many places where low-lying paths are found.

Bridges being washed away at river mouths: this resulted from extreme rainfall events with surface run-off perhaps exacerbated by wind farm development in nearby hills along the John Muir Way, East Lothian.

Heavy rain events: a number of coastal paths have been affected by prolonged wet spells, which have led to surface scour on the Banff Coastal Path, through to significant land-slips around Stonehaven.

3.1.3 Riverside Paths

Torrential rainfall / flood events: there are a number of examples of under-mining and over-washing by swollen rivers on the Clyde Walkway, Lanark; Rivers Tyne and Esk, East Lothian and River Almond, West Lothian. The path surface has been stripped and bank washed away on the Mains Burn, Oatridge, West Lothian.

On the river Don at Port Elphinstone, Inverurie a path was constructed in 2001 using Fibredec™ (a proprietary bituminous spray and chip construction with glass fibre for added strength). A large flood event in 2003 ripped under the edge of the path at one point and then lifted the surface as a single sheet causing widespread damage to the path.

On the Dufftown Spur of the Speyside Way (a disused railway line) the path was temporarily closed in 2001 as a result of a landslip following a prolonged wet spell and failure of old railway drainage features.

A number of paths have been made inaccessible by bridge destruction, such as on the Darn Walk, Bridge of Allan, Stirling. This resulted in a complete replacement of a different, more robust design.

3.1.4 Lochside Paths

High water levels after heavy rain combined with high winds producing severe wave action: these conditions led to path flooding and subsequent back-draining over and through the path on the West Highland Way, Loch Lomond. There has also been boardwalk destruction on Inchcailloch, Loch Lomond resulting from high water and wave action.

3.1.5 Urban paths

Torrential rainfall: this led to a rapid rise to spate conditions in a constrained burn and flooding of property at Freuchie, Fife.

3.1.6 Rural Paths

High rainfall: Deeside Way has been impacted by surface water from A93 which has been drained onto the path line – the road being seen as a higher priority. This has also occurred on a section of the Port Elphinstone path next to the A96, although this is more of a design issue. The John Muir Way in East Lothian has been flooded from adjacent farmland.

Storms: The Lion's Face path at Braemar, Aberdeenshire was closed for almost a year as a result of highly-localised storm-force winds (described as a tornado). The level of damage was extreme making passage through the woodland virtually impossible and required a specialist contractor to remove the felled and hanging trees. Damage to the path itself was considerable, both from root-plates and the clearance / extraction work.

3.2 Management responses to extreme events

Responses to these impacts have depended on the ability to secure additional funding, which in turn may have been dependent on the political pressure to respond. On the Dufftown Spur, alternative options were not considered to be suitable for the status of the route so the repair involved large scale civil engineering to reinstate the trackbed at a cost of approximately £100,000. Further flooding downstream in 2004 caused damage to other parts of the infrastructure, and led to the whole Dufftown Spur being closed while inspections were undertaken. This section of an official Long Distance Route was subsequently de-designated.

On the riverside path at Port Elphinstone a section of the damaged path was experimentally repaired in 2003 using a 100mm thick bituminous layer. This repair is still in reasonable condition in 2011, whereas the rest of the Fibredec path is at the point of failure (exposed sub-base). There have been numerous overwashings by the river during this period, which has caused the deterioration of the original surface.

Catastrophic events, such as the loss of a bridge within a community setting or part of a designated route, appear to be more readily addressed than the incipient damage to a path surface from heavy rain. Some local authorities have used reserve funds to deal with such contingencies (e.g. East Lothian Council used reserve funds for some repairs of the John Muir Way).

The management response to the extreme rainfall on Beinn Ghlas was to install sizable wooden gutters as 'first aid' in slowing down water flow and erosion until finances allowed a more sensitive and sustainable solution. This approach was effective and was carried out solely by staff and volunteers. Subsequently, with the advent of the CCS footpath team and the establishment of contract work, stone was flown in and the length of path brought up to a manageable condition, at a cost of around £75,000.

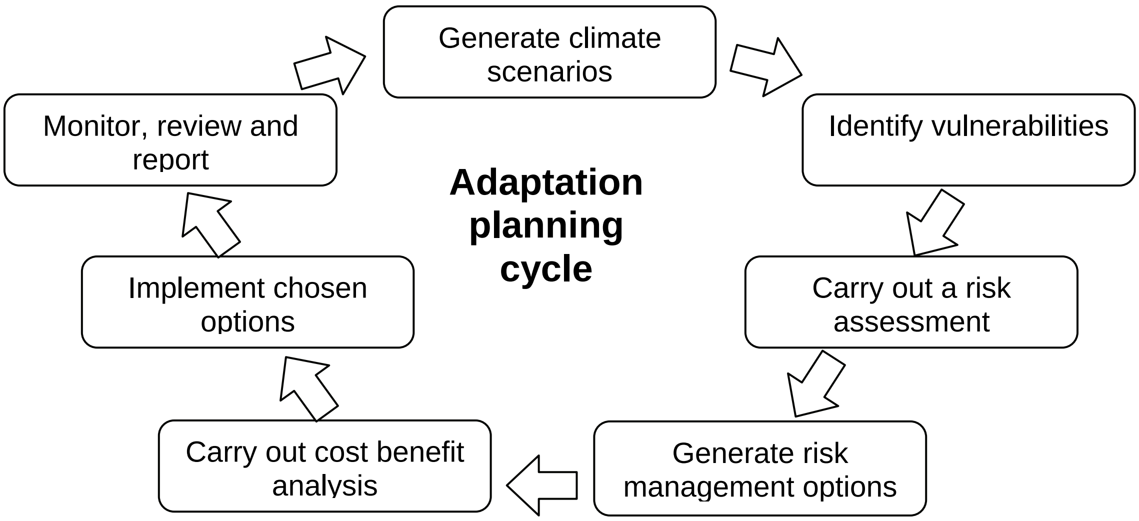
In some situations, designs are already being adapted to cope with more extreme weather events: bridge heights are being raised and innovative features such as modular construction and automatic water pressure valves are being trialled on two bridges. The Clyde Walkway has been upgraded to a sealed surface to cope better with regular over-washing. Some managers are now questioning the sense or value of planning paths on susceptible locations, e.g. by the North Sea and along river flood plains. Many approaches were suggested that could be more widely adopted in the future and these are outlined later in this report.

4 ASSESSMENT OF CLIMATE CHANGE EFFECTS AND ADAPTATION OPTIONS

Working from an understanding of the scope, magnitude and uncertainties of predicted climate change and the associated impacts on paths, the risk-based management process outlined in this chapter can be used to investigate what adaptations might be made to minimise these potential effects. This approach assumes that a 'do nothing' option (i.e. ignore the potential for climate change to impact on paths) is not viable.

The process builds on the adaptation planning cycle used by the Department for Transport (Figure 4). UKCIP's Adaptation Wizard is another tool that can be used to better understand your vulnerability to climate change and the actions that you might take to adapt.

Figure 4: Climate change adaptation cycle



Each of the aspects of the Adaptation Planning Cycle is considered below.

4.1 Identify vulnerabilities

Chapter 2 outlined the potential impacts of climate change on paths, and the summary Table 7 and Table 8 can be used to identify the vulnerabilities of your network to the acute and chronic pressures that have been highlighted in chapter 1.

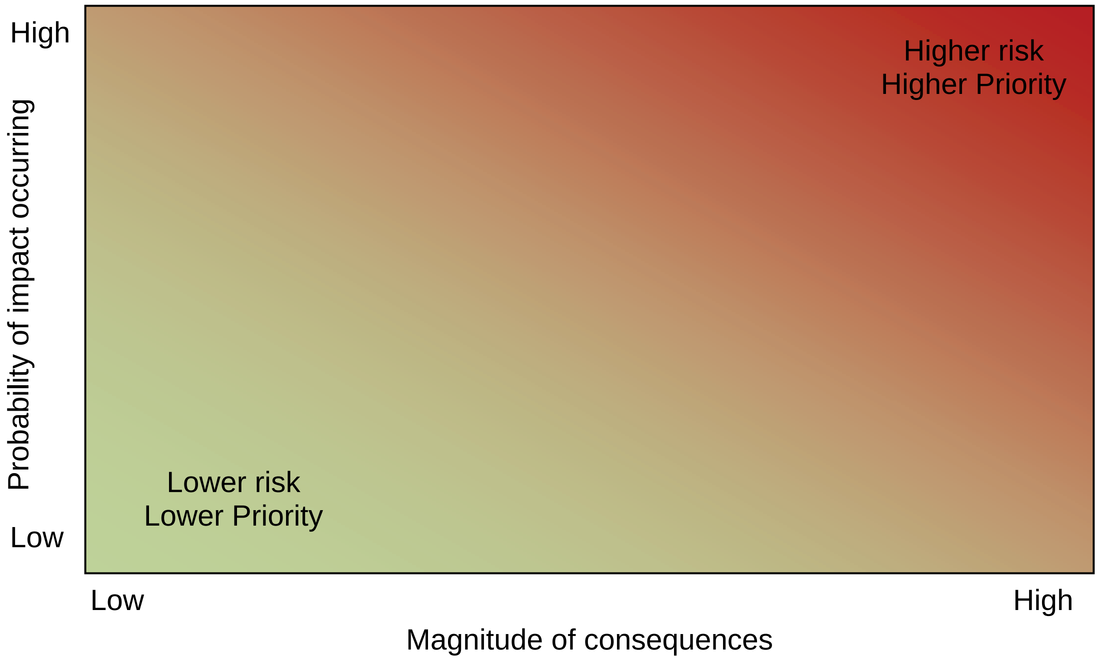
It will important to assess the risk of climate change impacts within the context of a path network to help identify implications beyond individual path sections or infrastructure items. For example, community path networks with river crossings may have more serious consequences for users, and therefore be at higher risk, compared to those without. Assessing the risk of a whole network should help pinpoint these key links and identify what management options may be appropriate.

4.2 Carry out a risk assessment

Having identified how a network as a whole might be vulnerable to climate change, further investigation may be necessary to understand the level of risk that this represents. The risk assessment process involves assessing the probability, or likelihood, of an impact occurring and the magnitude, or consequence, of the impact should it occur. Risk represents the product of these factors (i.e. risk = probability x magnitude).

Impacts that are highly likely to occur, and which would have serious consequences if they did occur, would be assessed as high risk, high priority impacts. Impacts that are unlikely to occur, and would have minimal consequences if they occurred, would assessed as low risk, low priority impacts. This relationship is highlighted in Figure 5.

Figure 5: Comparing priorities and risk



A key issue for assessing the risks associated with climate change impacts on paths is distinguishing, and prioritising, between impacts with a high probability but relatively minor consequences and impacts with a low probability but potentially catastrophic consequences. Assessments should therefore be carried out separately for chronic and acute impacts of predicted climate change. The steps involved in the risk assessment process are described in Appendix 6.

This process can be used to determine the risk of potential climate change impacts on current path infrastructure, and thereby assist in identifying and prioritising appropriate action. Detailed risk assessments of climate change impacts should be carried out when planning any new path project, taking account of projected changes in climate.

4.3 Generate risk management options

The outcome of the risk assessment will help inform management decisions. Following the assessment, controls to adapt to these risks can be identified and planned for accordingly. It is likely that where the assessment identifies high risks, higher priority should be given to adaptations that reduce the risk to an acceptable level. However, there may be instances where a lower risk has been assessed, but opportunities arise (e.g. through adjacent land use change) to implement adaptations of the existing path infrastructure to better manage the identified risk.

For each path or path network a decision will need to be made about the level of acceptable risk for the particular situation. This will determine which of the available options, listed in Table 9, could be adopted to manage or avoid climate risks. In some circumstances the cost of adaptation may be too high and alternative strategies may have to be developed to manage the consequences.

Table 9: Generic adaptation options and implications

Option	Implications for path management	Example of actions
Business as usual	Construct and maintain paths to existing best practice	Minimum action to maintain a safe and serviceable path network. This may already include contingency plans, monitoring changes to path condition and routine repairs / replacement.
Future-proof designs	Construct new path infrastructure to higher specification Construct new path infrastructure in appropriate locations	Updating design requirements including technical standards and specifications to provide additional capacity and/or functionality in the event of gradual climatic change or ad hoc weather events.
Retro-fit solutions	Adapt existing path infrastructure to increase resilience	Modifications to existing path infrastructure. Determine where (all sites or high risk sites) and when (now or at a certain threshold) action needs to be taken.
Develop contingency plans	Reconstruct key path infrastructure Downgrade or abandon paths	Pre-planned responses for when / if climate change risks are realised so immediate effects can be managed. This could be an option to use in the period before other measures are implemented or for when no other mitigation measures have been identified.

The main adaptation options and management implications that are applicable to paths are outlined in more detail below.

4.3.1 Construct and maintain paths to existing best practice (business as usual / future-proof designs)

All paths are likely to suffer from chronic effects of climate change (e.g. surface scour from high rainfall), which may be difficult to separate from ongoing 'wear and tear' and ageing of path infrastructure. However, appropriately designed paths that are constructed to existing standards and adapted to local conditions are considered to be best suited to withstanding the chronic pressures associated with predicted changes to climate. It is therefore important for path managers and funders to ensure that they are familiar with existing standards and insist on implementation of them for all work.

Construction standards are only one part of the management picture, so in order to remain resilient to climate change impacts, paths will continue to require management and maintenance using existing principles and standards. Providing that a path network has an established management and/or maintenance regime, it should be possible to adapt to the general climatic changes over time. This may require regular inspection surveys and periodic reviews of the maintenance tasks (e.g. every three years) to ensure that they match the prevailing condition of the path. Existing good practice should already include inspection surveys, although these may currently be restricted to load bearing infrastructure such as bridges.

4.3.2 Construct new path infrastructure to higher specification (future-proof designs)

A common approach in project-orientated management is to 'front-load' the lifetime cost of paths by specifying paths to a standard that require minimal annual maintenance. This potentially has an advantage of using capital funding to ensure that the infrastructure is robust enough to withstand predicted chronic effects of climate change. However, it is not possible to reliably calculate aspects such as the required maximum capacity for culverts and other drainage features under worst-case extreme rainfall conditions. In addition, attempting to specify infrastructure for defined worst-case events / capacities of uncertain probability and frequency may be difficult to justify in funding terms, particularly if there are limited resources available. It has to be recognised that it is impractical to build all paths to be capable of withstanding acute pressure of climate change. This adaptation option may be more appropriate for certain types of path infrastructure (e.g. bridges) or where moderately high risks are identified.

4.3.3 Construct new path infrastructure in appropriate locations (future-proof designs)

Careful consideration should be given to the siting of paths to avoid areas that will be at high risk from climate change impacts. Paths may need to be located further inland and/or on higher ground along areas of the coast at risk from storm surges, coastal erosion and/or sea-level rise compared to areas where the coastline is more robust and stable. Alternatively, low cost / low specification routes might be promoted on the beach or immediate hinterhand on the expectation and understanding that there are likely to be limitations on its use and it may need to move over time. Similar considerations would need to be given to proposed paths that are close to rivers.

It may not always be possible to build a path in the optimal location for a variety of reasons, including land ownership and competing land uses. In such cases, consideration should be given to whether other design solutions (e.g. different path specification) would help minimise the risks from climate change impacts.

4.3.4 Adapt existing path infrastructure to increase resilience (retro-fit solutions)

There may be opportunities to use the development planning process to enhance path networks through, for example, the promotion of green networks and planning gain. This could be a way of negotiating new links or improving existing routes to reduce path ‘squeeze’ and reduce risk on key links/sections within a network. This means that a strategic approach to network development and management remains essential, to ensure that weak links and potential opportunities are identified and the overall ‘security’ of the network is maintained.

For some older paths, where the path surface or drainage features are showing signs of wear, it may be possible to adapt the design at the point of repair or redevelopment, in order to account for predicted changes to climatic conditions. This may include installing additional, or larger, drainage features, or changing the surface treatment.

4.3.5 Reconstruct key path infrastructure (develop contingency plans)

An implication of climate change may be a shift in focus towards developing greater capability for dealing with large-scale acute damage, rather than hoping to pre-empt it. In countries that experience extremes of snow-melt and flooding, storm and wind-throw, management has been designed to routinely deal with the aftermath and paths are regarded as having seasonal access. For instance, the managers of the Milford Track in New Zealand assume they will have major clearance and repairs to carry out after every winter to get the route back into usable condition during the summer season.

4.3.6 Downgrade or abandon paths (develop contingency plans)

In situations where it is not possible to control the risk of damage and/or unaffordable to maintain the current standard of path, particularly due to acute impacts of climate change, it may be necessary to ‘downgrade’ formally constructed paths or even to abandon paths altogether. Aspirations and expectations for some coastal paths in particular may need to be re-evaluated. The risk assessment and cost benefit analysis should help to indicate and support such action.

4.4 Carry out cost benefit analysis

Wider consideration of the risk to path networks and their social and recreational, as well as environmental, consequences should inform the planning, design and management of paths. The costs and benefits of different options will be an essential consideration, particularly where resources are limited.

Chronic and acute effects of climate change on paths require different approaches in terms of funding and implementation. Chronic effects require ongoing attention through effective inspection and maintenance regimes that take account of changing conditions. Acute effects will inevitably be dealt with reactively, but some contingency planning should help to improve the response and decision making as and when necessary.

4.4.1 Whole life assessments

Carrying out whole-life assessments, a form of cost benefit analysis, would help to plan the costs and long term management for both existing and new paths. It is rare that recreational use of paths is the main cause of deterioration of well designed and constructed paths, and therefore environmental factors will be of main concern in assessing lifespans. It should be possible to appraise the life expectancy of different options in a given situation to demonstrate the real cost (rather than looking only at the initial capital expense).

For example, an unbound aggregate surface on a shallow slope may need minor top-up of surface materials every three to five years, compared with a possible ten-year repair-free span for a bituminous surface. Both would require the same inspection and maintenance of drainage and vegetation. However, over a 20-year life, the costs may begin to equate if the sealed surface requires more frequent repair or partial-replacement during the latter part of the period, assuming that neither option was affected by acute impacts. Factoring in these potential acute impacts may clearly skew the selection of the favoured option: the sealed surface is likely to be more resilient in most circumstances, although a detailed assessment would need to be made regarding the probability of it surviving intact.

For other structures, such as bridges, there are established procedures for assessing the whole life costs although these may need to be adapted to take into account the increased probability of acute impacts (based on the frequency of return of, for example, flood events).

Whole life assessments should not be restricted to new infrastructure, and retrospective evaluation of existing paths may highlight their resilience to climate change. This proactive approach allows path managers to consider a wider range of options than when faced with acute impacts and a need for an immediate solution and is a form of contingency planning.

4.5 Implement chosen options

The adaptation options outlined above are not mutually exclusive. Different options could be used on separate sections of a path network simultaneously, and various options might be applied to a particular path over time.

4.6 Monitor, review and report

Carrying out a risk assessment and implementing chosen adaptation options should not be a one-off task, rather should be reviewed periodically and revised as necessary over time.

Changes in land use (e.g. settlement development, forestry and agriculture) may occur after a path has been built that causes changes in the physical characteristics of the surrounding land (e.g. a different drainage pattern), with knock-on effects on the path.

Monitoring the occurrence of climate change events and their effects on paths will help inform future risk assessment prioritisations. Sharing experiences among path managers will also be an important part of the review process.

5 FUTURE PATH MANAGEMENT IN PRACTICE

In evaluating potential responses to the possible impacts of climate change and extreme weather events, consideration has been given to the four stages of path management:

- Planning
- Design
- Construction
- Management

It should be recognised that there is overlap between these stages and that they are integral and integrated parts of a coherent cycle of path management. The following analysis is essentially an extension of existing best practice, but viewed from the perspective of managing potential change caused by climate change.

A number of published documents set out the current best practice and agreed standards for path development and management, in various different aspects of the industry. These include:

- Upland Path Construction Standards
- Upland Path Management
- Lowland Path Construction Guide
- A Guide to Path Bridges

These documents have been evaluated and a number of recommendations have been made to adapt these documents in the light of predicted climate change. It is important to note that the current standards are considered to produce paths that are sufficiently robust to withstand the likely chronic impacts of climate change and the revisions to the guidance are relatively minor. The recommended revisions are outlined in Appendices 2 to 5.

5.1 Lowland paths

5.1.1 Planning

A good network should provide a range of access opportunities whilst integrating the challenge of climate change with the selection of routes and infrastructure. Where new paths are constructed the surrounding terrain and land use should be considered to ensure that there are no adverse implications that could be exacerbated by climate change. For example, field margins along cliff tops may be at risk of collapse under extreme weather conditions and an alternative (possibly secondary or informal) route may be needed to connect the end points of the cliff-top section.

A strategic approach to path development in the future is critical to ensure that no ‘weak links’ are introduced. Although it may be tempting to respond to all ad-hoc and opportunistic developments, they may have a detrimental effect on the security of a network if they are not assessed against the strengths and weaknesses of the existing infrastructure (e.g. new infrastructure could divert capital resources away from improving the key links, or in the longer term cause ‘overstretch’ of revenue resources for maintenance).

An early response to the potential impacts of climate change would be to undertake a full risk-based assessment of existing path networks (including both core paths and ‘wider networks’). This could be used to identify weak points in the network, alternative options and to determine a strategy for dealing with chronic effects on paths. Coupled with a whole-life analysis, this provides path managers with decision making tools to cope with climate change, rather than reacting to events on an ad hoc basis. This work could be undertaken by local authorities when, for example, reviewing access strategies and core path plans.

Access strategies may require to be updated to incorporate the potential influence of climate change in order to guide future development. These revisions to access strategies need to be incorporated into development plans and used to identify opportunities for improving recreational access that is robust with respect to climate change. Local Authorities should have procedures in place to plan for climate change and these may include localised data from, for example the UKCP Weather Generator: this more detailed information could then be used to identify whether there are particular weather risks within the area covered by the access strategy.

The process of core path planning should have helped to identify the needs and limitations of path networks across Scotland. Although the published plans may not have been selected using climate change as a priority constraint, the pressure to produce realistic and affordable networks has resulted in plans that have minimised the potential weaknesses and managed expectations of the public. When core path plans are being reviewed it may be helpful to include climate change information as an additional factor for consideration.

In the wider context of development planning, opportunities should be sought to incorporate revisions to access networks through the Local Plan to ensure that proposed developments include high quality provision that will be resilient to climate change and that existing weak links are 'designed-out' if an opportunity arises (e.g. through planning gain). Integration of recreational access within 'green networks' at an early stage of planning may help to secure more robust access networks and path managers / access officers could be encouraged to engage with these and other master-planning exercises.

5.1.1.1 Route selection

Where there is scope to choose the line of the path, consideration needs to be given to land uses that may have a negative impact on the path, or potentially help to protect the path against the predicted changes in climate. Ensure, for example that the path is not unnecessarily exposed to surface water, that any slopes are stable and that there are no external influences that are likely to reduce the capability of the path or network to adapt to climate change.

Where habitat enhancement schemes are being implemented, there may be scope for these schemes to provide additional or alternative capacity for paths which is better suited to long term adaptation to climate change. In some building developments, there may be opportunities for negotiating access that is integral with the overall landscaping and functional needs of the development and carefully chosen to avoid creating weaknesses in the network.

5.1.1.2 Accessibility

It is likely that climate change effects on paths will have a disproportionate impact on certain user groups, most notably wheeled users. Retaining surfaces within the current standards may become more challenging and could lead to the use of more sealed surfaces, which may have a detrimental effect on the landscape and setting of some paths. Public bodies have a duty to comply with equality legislation and will need to review 'reasonable adjustments' that can be made to accommodate all types of path users. However, the concept of 'least restrictive option' should be retained within any path planning process to ensure that necessary compromises between path function and environmental conditions are considered.

Although these challenges cannot be used to mask prejudices or unwillingness to provide infrastructure for inclusive access, it may be necessary to assess the practical levels of provision and work. This should then inform the expectations of all users to ensure the investment in lowland path networks is both as inclusive and sustainable as possible.

5.1.2 Design and construction

The increasing tendency to use civil engineering approaches and standards for formally constructed paths is beneficial in adapting to the predicted effects of climate change by using increments in specification rather than ad-hoc changes to design. Natural heritage sensitivities should be taken into account in relation to such changes in construction specifications.

5.1.2.1 Surfacing / base construction

The choice of surfacing needs to reflect the path setting and the likely use, but it may be appropriate to use sealed surfaces more widely to reduce the effects of surface water on gradients. This may be through specifying a sealed surface at the construction stage or retrospectively upgrading paths if or when resources allow (such as the use of a 'spray and chip' top dressing).

With this in mind, the preparation of base layers of paths with unbound surfacing becomes more critical to ensure that upgrading can be done without complete reconstruction. Therefore, where a risk assessment has identified the benefit of using a sealed surface but current resources do not allow this level of investment, the base layer formation should follow the specifications for the appropriate sealed surface.

Where a sealed surface is impractical (e.g. where the location is too sensitive or access for the necessary machinery is not possible), the inclusion of fines (clay / silt) in the surfacing should help to bind aggregates and may prolong the life of the surfacing. In accordance with current practice, measures to minimise or reduce the gradient should be taken and a shedding finish will help to reduce the risk of scour by surface water (either using a camber or cross-fall)

Natural surfaces may be more appropriate on sections that are prone to damage as a result of climate change in order to avoid raising expectations about accessibility that cannot be sustained. This would also allow resources to be channelled to path sections that can be adequately maintained within defined standards and provide a consistent user experience for the full range of users across the network.

5.1.2.2 Drainage

In many cases lowland paths are built with covered drains / culverts to minimise the barriers to access. Existing guidance states that consideration needs to given to the likely capacity required to cope with elevated flow rates – the existing recommendation of sizing culverts so that they do not run more than half full means that, if followed, the current procedure should be adequate for potential increases in rainfall. However, where capacity is found to be inadequate, installing additional small drains is considered to be more effective than increasing the size of existing culverts, given the potential for blockage (i.e. a single large culvert that blocks is more likely to have a catastrophic impact compared with a smaller blocked drain with others nearby that continue to function). This also means that it may be possible to ‘retro-fit’ additional drainage to existing paths where this is found to be necessary.

Calculation of the likely surface water flow is complex, and needs to be site specific. However a ‘simple area run-off’ method shows that there is a linear relationship between the rainfall intensity and peak flow: an increase in the predicted intense rainfall event is likely to give rise to a proportionately greater run-off and drains should be sized accordingly.

Consideration needs to be given to adjacent land use and the potential for surface water to inundate the path. Neighbouring land managers may need to cooperate to ensure that their activities do not have a negative impact on land drainage or surface water within the path corridor.
In cases where some inundation is expected, such as on flood plains, current guidance recommends using ‘through-drainage’ to prevent the path becoming a barrier to flow. It should be designed to minimise any restrictions that could lead to back-up of water, which causes increased flow at the point(s) of constriction and increases the risk of damage to the path or drains. Depending on the outcome of the risk assessment for a given flood plain the bore of culverts may need to be over-specified with respect to current conditions and may lead to the path level being further raised: the landscape implications of this approach would need to be assessed to ensure that it is still in keeping, and it would have cost implications for the additional groundworks.

It may be appropriate to integrate the principles of SUDS (Sustainable Drainage Systems) to help adapt to the potential for flooding. This includes ensuring that flow rates are not increased, improving the permeability of the surface where practicable and providing adequate temporary storage if necessary to prevent downstream problems.

5.1.2.3 Bridges

A key consideration is the potential weakness introduced to a path network by river crossings. The location needs to be carefully considered with respect to predicted spate flows, and the span and abutments designed to avoid entrapment of flood debris. Following existing good practice should provide a sustainable solution providing that the calculations for spate levels take into account predicted changes to the climate.

Investigation may be required to design modular units that collapse / wash out rather than resist extreme spates. It is uncertain whether such designs would be viable or cost effective.

5.1.2.4 Engineering features

Large scale embankments, cuttings or revetments should be avoided if possible as they are likely to require considerable earthworks which could be susceptible to failure in wetter winters through soil saturation, and during intense rainfall. Existing engineering features may need additional reinforcement or modification to reduce the risk of failure – this issue should be identified during the risk assessment process and preventative measures undertaken. These could include reducing the angle of slope, improving the soil-binding capability of the vegetation, using geotextiles or soil reinforcement.

In coastal areas it would be difficult to justify the use of hard engineering solely to protect a path particularly in exposed areas where storm surges are likely to occur. There may be overriding economic or social reasons for improving coastal defences, and the presence of a strategic path link may help to build the case, but there may be a stronger case for downgrading the status of the path to an informal route.

Where engineering works cannot be avoided, it may be appropriate to use soft engineering techniques, such as willow spiling, to reinforce slopes and riverbanks in favour of hard engineering solutions.

5.1.3 Management

5.1.3.1 Inspection

The introduction of risk-based management of path networks should provide a clear regime of inspections for paths and associated infrastructure. This regime should include the frequency and expected competencies of the inspector, as well as the detail of tolerances in condition. In addition to regular inspections it may be necessary to plan for ad-hoc inspections of certain features (e.g. bridges) following extreme weather events. These additional inspections will help to identify acute effects that may require capital expenditure and/or implementation of contingency plans (such as temporary re-routing).

Where resources do not provide for separate inspections alongside maintenance visits, a formal reporting system could be introduced to ensure that the condition (prior to, and after) of path infrastructure is recorded as part of maintenance visits and acted upon subsequently – this would help to highlight non-routine maintenance requirements and to plan resource allocations more effectively.

5.1.3.2 Maintenance

In common with other aspects of the ‘transport network’, the key issue for adapting to climate change is effective maintenance. Therefore regular (which may or may not be frequent) small scale maintenance is likely to arrest the deterioration of paths that would be susceptible to the ‘magnified’ effects of the climate compared with current conditions – i.e. helping the path to cope with chronic effects. Where it becomes apparent that particular features or sections are failing repeatedly the option should be taken to re-evaluate the specification rather than replace / repair like-for-like.

Some maintenance tasks may need to be adapted to account for the predicted climate, including, for example, vegetation management. It may be necessary to deploy additional cutting cycles to account for an increase in the growing season, but access to the site by machinery may be compromised if increased waterlogging occurs at certain times of year. Some adjustments to the timing of cutting may also be necessary to account for changes to the growing season. This may require additional flexibility in resources to enable routine work to be undertaken. Increased use of local volunteers could help to address this issue, although this may not be an appropriate solution where there is a large amount of vegetation management required.

5.1.3.3 Adaptation of existing infrastructure

Within the timescales of predicted climate changes it is likely that most paths will require 'refurbishment' works to retain or enhance their accessibility and/or function. The planning process outlined in the two sections above should be used to identify where existing infrastructure has potential weaknesses with respect to climate change, and opportunities can be investigated for securing funding under the auspices of adapting to potential impacts. This may result in significant adaptations, including re-routing, which could be more cost-effective than upgrading infrastructure to cope with predicted conditions.

Where drainage features are being repaired or replaced the capacity of ditches and culverts should be calculated using predicted climate conditions rather than the contemporary conditions. This approach should be used for other features such as bridges.

Future climate models and patterns of emissions may provide better indications of the probability of the outcomes than is currently possible and 'most probable' predictions should be used to anticipate the specification of replacement infrastructure.

5.2 Upland Paths

5.2.1 Planning

Upland paths are managed in landscapes that are highly valued for their natural and cultural heritage. Any adaptations to take account of climate change impacts need to incorporate this sensitivity. For instance, raising the path line or constructing bridges above potential flood waters may not fit easily within a setting that in other respects appears wild and unmanaged. The widespread use of turf-lined drains may not be acceptable in sites with sensitive natural heritage features (such as designated habitats).

The response in planning terms can be summarised: plan for the whole path in its setting, integrated with all the values associated with that piece of land, but bearing in mind all of the potential effects that climate change may bring. A "green survey" or path assessment as outlined in Upland Path Management Manual is a good starting point.

5.2.1.1 Surfaces

To protect path surfaces from scour, route paths away from potential flood areas. Reduce gradients to find a more sustainable line and consider off-path drainage to intercept water. These options are dependent on cooperative land management and may be subject to planning restriction: planning permission may be required for a significantly new path line whilst SSSI and Natura designations may restrict wider drainage schemes.

Consideration should also be given to assessing the potential for slumping (schistose soils over tilted schist strata) and re-routing a path if necessary. However, this is probably a localised problem potentially affecting paths in the Breadalbane / Loch Lomond and the Trossachs National Park area and on slopes over 30-35 degrees.

5.2.1.2 Drainage

It may be useful to intercept surface water further from the immediate environs of the path and divert it away or manage its flow across the path line. Sufficient resources will need to be budgeted for robust drainage features including turf-lined drains. Whilst there is a cost implication for construction, the maintenance requirements of turf-lined drains are reported to be much lower than for bare ditches; but note the caveat in 5.2.1 above regarding habitats.

5.2.1.3 Users

User expectations may need to be adapted to cope with more extreme weather events: cross drains inhibit cycling for instance and surfaces suitable for wheel-chair access may be too costly to maintain. However, within an upland path network there should be opportunities for all, and it is important that consideration at the planning and design stage is given to the least restrictive options for access.

Risk assessments should consider how extreme weather events might jeopardise visitor safety; for instance, provision of a car park and a well surfaced path may encourage users to go beyond their safety zone, for instance in terms of a spate-prone burn crossing.

5.2.1.4 Staff

The potential impact of changing weather on staff welfare and safety needs to be considered. The ability to work on into the winter months because of milder winter weather may bring added risks, for instance in working or walking in to the site in short day-light hours. There may also be chronic effects from longer winter working whilst high winds and high temperatures / exposure to more sun-light could all carry risks and sudden precipitation events can render previously safe routes impassable. Managers will need to set up systems to monitor effects on staff and adapt to impacts and this will have a cost implication.

5.2.2 Design

5.2.2.1 Surfaces

Path surfaces will be better protected from wash-out if they are constructed above the surrounding ground/vegetation. Surfaces may be cambered to shed water sideways off the path. Path stability is enhanced by the addition of anchor bars, however their frequency needs to be assessed for a given site, as does that for water bars. Where possible, a reduced gradient should be sought. There are obvious cost implications and potential impacts of increased stone requirements in higher construction specifications. A cost-benefit analysis may well suggest finding a more sustainable line.

5.2.2.2 Drainage

A whole path view of the path in its surrounding landscape may offer the best solution to drainage issues: build the path high and dry, route it onto drier ground and consider channelling water away from the path area at a distance from the path. Piped culverts tend to block with dead vegetation and replacing them with open cross drains is a capital outlay that may well be cost effective in the longer term. On paths regularly used by ponies or quad bikes, larger bore pipes and an increased frequency of maintenance may be a more practical answer. Ditches should be designed to cope with increased flow rates and wider and shallower with turf lining is now recommended in most situations.

5.2.2.3 Stonework

It should be possible to ensure stability of all stonework by specifying adequately sized material which is bedded in sufficiently e.g. to half the stone's volume. Revetments should be designed so that the stonework would stand alone and not rely on packing material to act structurally. Whilst this is current best practice, climate change impacts demand that path managers ensure that those standards are implemented in order for paths to withstand the chronic impacts of climate change predictions.

5.2.2.4 Bridges

One option is to construct higher and more robustly. However, cost and landscape considerations might favour a lighter and potentially more fragile solution that can be easily removed or replaced. For example, easily replaced wooden spans, with minimal or no handrails, would offer less resistance and opportunities for damming in spates. In sites particularly prone to snow melt/high rainfall (perhaps around the Cairngorms) experimental removal of bridge slats in winter could be tried.

However there is no tradition of seasonal infrastructure in Scotland so serious thought would need to be given to the potential risk to users and how to communicate any change – both in terms of informing the debate and implementation on the ground.

5.2.2.5 Re-vegetation

Path managers should be able to plan and design with greater confidence that path-side vegetation will grow more vigorously in changing climatic conditions. However, this positive prediction may be countered by dry summers, particularly on poor soils such as in the Cairngorms. The grazing regime may change as environmental and socio-economic conditions dictate, with a consequent impact on path-side vegetation. There will also be issues surrounding the impact of dry, hot summers on actual re-vegetation practice, but specification should take account of the best season within which to carry out this work.

5.2.3 Construction

5.2.3.1 Surfaces

More winter precipitation and more frequent downpours will necessitate greater attention to surface construction. The design principles mentioned above will help to protect surfaces but they will still be required to cope with increased water impacts. Material should be as coherent and well bound as possible, and compacted to resist frost heave and wash-out. Recent developments in the Cairngorms offer hope that granite-derived material can be effectively bound through careful sourcing of clay-rich gravels. However, there may be a need for further experimentation across Scotland to ensure consistent standards of surfacing.

It may be unrealistic to try to prevent acute rainfall events from washing over paths, but management has to deal with the chronic pressure of annually higher winter rainfall and potentially more frequent freeze / thaw activity. A path that can cope with chronic impacts is considered to be more resilient to the occasional acute impact.

5.2.3.2 Drainage

Drainage features on and across paths should be built to cope with the predicted, gradual increase in winter precipitation levels, for instance by up to 30-40% in the wettest conditions predicted. Ditches should be either stone-lined or, preferably, turved to reduce wash-out risks. Although stone lining may appear expensive, the cost of catastrophic failure may be higher, turfing may be more cost effective and less visually intrusive. The use of machinery should be explored, on grounds of efficiency, cost and the health and safety of path workers.

5.2.3.3 Stonework

All stonework should be dug-in proportionately to cope with the anticipated erosive impact of increased water. Path-side revetments should be of a sufficient size and constructed in such a way as to be resilient to frost heave and wash-out.

5.2.3.4 Revegetation

Existing best practice in terms of storing and laying turves should be utilised. It may be necessary to water turves during these operations in long dry spells. Clipping vegetation before cutting and taking a bigger “root-ball” may also help but revegetating outwith drought periods should be the aim.

5.2.3.5 Staff

Path managers and workers need to be aware of the increasing onus on the delivery of quality design and construction to achieve paths resilient to the effects of a changing climate. During construction they should remain vigilant to any signs of stress in colleagues from the effects of more extreme weather conditions.

5.2.4 Management

5.2.4.1 Maintenance

The chronic impacts of climate change on path surfaces, drainage, stonework and vegetation make the proper maintenance of all paths ever more important. Surfaces will deteriorate, drains clog, stonework fail and vegetation wash out – this is inevitable under any conditions but more so in more severe weather. Whilst maintenance cannot cure the excesses of, for instance, extreme rainfall on melting snow, conversely climate change should not be used as an excuse for insufficient maintenance to deal with the chronic changes outlined above.

The need for an effective maintenance regime will be coupled to more frequent monitoring of path condition; there is the potential for volunteers to become more involved in this aspect of path care. In the Lake District the Fix the Fells Project uses volunteer lengthsmen to monitor path condition and carry out small scale maintenance tasks. All paths are coded red, amber or green depending on the path manager's judgement regarding rate of change and maintenance needs, and the frequency of inspection graded accordingly, from "regular" to annual.

The uplands are perhaps more resilient than lowland path networks to both chronic and acute symptoms of climate change. But there will be occasions when extreme events lead to catastrophic results – it will not be possible to predict the location or timing of such events. Appropriate responses are necessarily difficult to plan, but responses should be timeous to prevent consequential damage. Some form of contingency or reserve fund (as local authorities have for flood damage) is needed. Funders need to consider how this might be established and how it could be accessed at short notice and with a minimum of bureaucracy. Funders should also have a deeper appreciation that paths that have been improved with the help of grant aid may occasionally fail owing to extreme events and that in such circumstances grant conditions can validly be waived.

With greater weather impacts comes greater uncertainty as to how well new path work will stand up. Consideration could be given to a greater emphasis on follow-up work on a path to take account of more hostile conditions. This could be part of a funded path improvement programme rather than viewing path repairs as a one-off capital investment.

5.3 Regional variation in paths

Although there are some regional differences in the predictions of climate models, the inherent variability in the emissions scenarios and probabilities of change mean that the implications for paths are unlikely to be significantly different across the country. Existing practice shows that there are local styles of path construction, which have developed to cope with prevailing conditions, particularly with respect to drainage, and those differences are likely to be only marginally accentuated through climate change, given that change is predicted to be gradual rather than punctuated.

The regional differences in path construction style and management tend to result from the traditional use of a path, availability of local materials and the underlying geology and geomorphology, but there are some differences that result from the local weather and climate. These differences are most notable in upland paths, where there is a greater reliance on locally available stone for building drainage features, and as-dug surfacing. For example, areas with rock that breaks into large flat surfaces (e.g. slate and schist) may have stone culverts, particularly on those used as pony-paths for stalking. In areas with more rounded stone, fords have been used in some places to facilitate access by ponies. Large open cross drains have been built more recently, their size being partly to cope with long periods without routine maintenance. Adequately sized fords may be able to cope with elevated water levels, whilst presenting less of a barrier to some users.

Availability of surfacing materials can also influence path design, particularly where there is a lack of clay / silt to help bind particles and stabilise the surface. In some cases stone pitching has been used on extended lengths of path, even at relatively shallow gradients, whereas less intensive techniques have been trialled using aggregate surfacing with anchor-bars to reduce the gradient. Some further monitoring and reporting on the long-term maintenance requirements is required to provide a whole-life assessment of cost, but this technique may be usefully applied more widely to help reduce the potential impact of water on unbound path surfaces.

5.4 Cost implications of dealing with chronic impacts of climate change

The variability of path settings, geography and management arrangements make it difficult to draw together meaningful estimates of the cost implications for paths in Scotland – either as a whole or on a regional basis. However it is possible to give some insights into the types of adaptations that will have a bearing on the funding requirements for individual paths and networks, and these have been divided into design, construction / repair (capital investment) and ongoing management (revenue costs).

5.4.1 Adaptations to design, construction and repair

The specification of drainage features may need to be increased to account for higher rainfall – this may be additional drains or water bars rather than larger ones to ensure that no single drainage feature can cause catastrophic damage if it fails (although this should already be standard practice). Larger diameter culverts and pipes have proportionately higher costs in terms of materials and the labour required for installation and more frequent placement of drains likewise increases the cost. In some cases there will be a need for retrofitting, which may have higher unit costs than the equivalent infrastructure at the time of path development – this is partly due to the cost of locating plant as well as management costs to design and survey existing paths.

There are cost implications of using turf lined drains instead of open ditches, but both of these may be cheaper than the current use of filter drains on lowland paths. For upland paths the cost implications of using turf-lined drains instead of standard open ditches is estimated to be 30-40% extra. However, this capital increase is potentially offset by much reduced annual maintenance cost as the drains are more resilient to erosion and less susceptible to blocking (and subsequent failure).

In lowland paths there are considerable cost implications of moving from unbound or natural surfaces to sealed surface construction. It is very difficult to generalise about the actual costs of paths but where an aggregate path with a standard specification might cost around £30 per metre, the equivalent sealed surface path (e.g. a bitmac path) would be likely to cost upwards of £100 per metre.

5.4.2 Adaptations to management and maintenance

In the lowlands it is often difficult to quantify the cost of maintenance, or at least attribute it as ongoing management cost. This is partially a result of funding regimes and budget allocations that penalise revenue spending. It is likely that paths will require some form of inspection and maintenance regime in order to remain fit for purpose in the light of predicted climate change impacts, and there will be a cost in developing these plans (this cost is highly variable depending on the connectivity and nature of the paths). These plans could then be used to estimate the current maintenance burden and potential risks that need to be addressed and estimates of the likely increase in costs are difficult to generalise. However, the analysis of likely chronic impacts highlights some areas that may have measurable additional costs:

5.4.2.1 Vegetation management

Some paths have the path-side vegetation cut two or three times a year. Extended growing seasons could mean than an extra cut is required (i.e. 50% or 33% increase in cost, respectively) although it may be possible to reschedule the final cut where there are already three maintenance visits. Conversely, in summers with extended dry periods, vegetation growth may be impeded, meaning that additional cuts are not necessary. Therefore it is possible that over a five year period, costs increases for vegetation management can be more realistically estimated (e.g. an extra visit in two of five years, represents a total increase of 20% or 13% over five years respectively for current two or three visit annual maintenance).

5.4.2.2 Path inspection

In order to ensure that chronic pressures do not result in adverse impacts, there is a requirement to undertake inspections of all paths on a frequent basis, with a minimum of an annual visit. Some of this burden could be passed to appropriately trained volunteers, but there would potentially be a cost in training and managing the volunteer effort and data collected.

5.4.2.3 Upland path maintenance

In 2010 the Cairngorms Outdoor Access Trust budgeted £30,000 for 93 kilometres of upland path maintenance. This is based on detailed path surveys producing an improvement and maintenance plan. As each path varies in its requirements, based on the baseline condition as well as use and environmental factors, specific figures cannot be given for upland path maintenance needs: a plan is required for each. However, a 10-20% increase in maintenance costs attributable to chronic climate change impacts seems reasonable.

5.5 Raising awareness and sharing knowledge

There appears to be a relatively high level of awareness of the potential for climate change among the path managers interviewed, although its implications for paths are less well understood. There are examples of good practice in dealing with extreme weather events and there is potential to share knowledge about dealing with different climatic conditions across Scotland. However, there are currently limited opportunities for sharing this knowledge although there are mechanisms in place to allow communication e.g. the Upland Path Advisory Group (UPAG), Scottish Countryside Access Network (SCAN), and potentially the Scottish Access Technical Information Network (SATIN).

The use of these networks to promote better awareness of the implications of climate change for path design construction and management may be an effective method of reaching practitioners and providing practical advice. However, UPAG and SCAN are almost mutually exclusive in their membership so may provide limited opportunities to share knowledge between upland and lowland path settings. SATIN has the potential to provide a 'vehicle' for hosting case studies and organising networking / training events, although to date there has been limited activity as a network.

Beyond the path practitioners, there may be benefit in highlighting the issues to policy makers and funding bodies, although there has been mixed success in engaging with these groups with previous topics that are not 'immediate' or central to their own aims. Any communications would therefore need to be targeted towards dealing with specific issues that relate to an organisation or sector rather than trying to tackle things generically. These communications would need to be framed within a context that is relevant to the organisation or sector, rather than assuming that the importance of this issue will be recognised by a person whose 'core responsibilities' lie elsewhere.

5.5.1 Developing a programme of training and awareness

There need to be two complementary strands to any programme, targeted towards specific audiences:

- Practical measures
- Policy and funding

Although there is some overlap between the information required, experience shows that events for a mixed audience rarely encourage attendance, particularly where people perceive that they have more pressing priorities or workloads. Therefore these strands should be jointly developed but delivered separately for the respective target audiences

5.5.1.1 Practical measures

The main target audience would be path managers from lowland and upland locations across Scotland, to provide a forum for sharing existing knowledge and an opportunity for Continuing Professional Development (CPD). This could be a series of site visits (lowland and upland paths, with a variety of settings) and a workshop session, possibly taking the form of a two day 'conference'. The key issues that could be highlighted for practical measures would include:

An introduction to climate change predictions
This would provide the context of the climate change models and the different acute and chronic pressures that will be placed on paths.
Long term implications for path management
This would include emphasising the need for ongoing maintenance planning and monitoring change. It would also introduce the concept of risk-based management for climate change and the need to allocate resources.
Ways of preparing for climate change
This would highlight practical steps for ensuring paths remain resilient and case studies of responses to extreme weather events.

5.5.1.2 Policy and funding

The main target audience would be decision makers and policy advisors in the main national organisations and access authorities that manage or fund (or potentially fund) paths. It may be difficult to motivate senior managers to attend an event and the effort of aiming at this level may not be rewarded. The briefing note (see appendix 6) may serve to highlight the issues to senior managers, with the main focus of more detailed programme of awareness-raising focussed at a lower level. Further work on identifying job roles and individuals would be necessary.

At the policy and funding level it is likely that lowland and upland paths would most helpfully be dealt with separately – there may be some overlap in interests, but the benefits of bringing such a diverse group together are not so well defined as for path managers. The programme could however highlight the issues for other path settings to give a more complete view of the implications of climate change. It may therefore be appropriate to hold two seminars, each of a day, with a site visit and a workshop session. The key issues that could be highlighted for policy and funding would include:

An introduction to climate change predictions
This would provide the context of the climate change models and the different acute and chronic pressures that will be placed on paths
Potential impacts on investment and accessibility of paths
This would include an outline of the nature and scale of impacts and the implications for investment and path use.
Ways of preparing for climate change
This would highlight the difference between planning for chronic impacts and reacting to acute impacts. It would also include practical steps for ensuring paths remain resilient potential funding models to deliver these requirements.

6 CONCLUSIONS AND RECOMMENDATIONS

The main conclusion from this study is that the key to ensuring that paths and path networks are resilient to the predicted chronic impacts of climate change is planned, preventative maintenance. It will, however, be very difficult to clearly attribute changes in path condition to climate change and therefore count the cost directly, or bid for resources. In particular acute impacts cannot be reliably predicted in terms of location or timing.

6.1 Management

The adoption of a risk-based management approach to path management would help to identify existing weaknesses and opportunities to adapt to climate change. It will provide a coherent framework for making decisions about accessibility that are not focussed solely on cost and give strategic insight into the future challenges of meeting the needs and expectations of path users. Although it will not eliminate the possibility of damage to paths, this approach will allow path managers to minimise the risks and identify the scope and scale of resources required in the event of acute climate change impacts occurring.

It is recommended that risk-based management be introduced to identify the most resource efficient methods of providing high quality access for a full range of users across different path settings.

6.2 Standards

The existing best practice in construction of paths and agreed standards for path management are considered to be sufficient to cope with the predicted chronic impacts of climate change. There are some minor adaptations that could be made, although these are related more to the quality of planning rather than specification of path features. It is not therefore necessary to undertake a fundamental review of path design and construction in order to meet the challenges and opportunities of climate change. However, funding bodies and path managers need to ensure that those standards are implemented and adapted to local needs.

Existing guidance documents need to be updated to incorporate the findings of this research and highlight where particular issues and risks need to be addressed. This work represents minor additions and editing rather than large-scale re-writing.

It is recommended that the suggested adaptations to existing guidance and standards be incorporated and that funders are encouraged to take account of an applicant's response to potential climate change impacts when making funding decisions.

6.3 Funding

Resilience of paths to the pressures of climate change is heavily dependent on the existence of inspection and maintenance within a defined management framework. Unfortunately the current funding regime of capital investment with limited or nonexistent funds for aftercare, particularly in upland paths, is not conducive to adapting to climate change. The security of current investment is questionable where there is no ongoing commitment to management, or where this is classed as ineligible for funding.

It is considered likely that climate change will exacerbate the inherent risks in a capital-focussed approach. This is particularly the case with upland paths where there are limited sources of funding and most contributions towards upkeep are made on a voluntary basis (either through cash donations or labour).

It is recommended that a fundamental review of investment strategies is undertaken to ensure that paths and path networks can be adequately resourced to be resilient to chronic pressures from climate change.

6.4 Sharing knowledge and experience

The current awareness of climate change and predicted impacts on path design, construction and management is variable within Scotland and there are differences in the priority given to planning for these impacts. It is not clear whether key decision-makers, including those in funding bodies, have any particular awareness of the potential implications of climate change for paths.

It is recommended that an event, or programme of events be organised at a national or regional level, and that promotional materials be developed to highlight the key issues for a non-technical audience.

The evidence of climate change impacts on paths is currently based on individual experience and hearsay. There would appear to be a need for a more structured approach to gathering information. Individual local authorities in Scotland are now starting to collect climate change impacts profiles (LCLIPs) and this could be a vehicle for stimulating regular monitoring of events and sharing of information.

It is recommended that a sector-specific user group be created and coordinated under the Scottish Climate Change Impacts Partnership.

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Appendix 1: Write-up of workshop held for path managers

Break-out Session - Upland Paths

How do paths shape up in relation to change predictions?

Strength	Weakness
Well built x2 Good drainage Ridge paths not susceptible to wash-out Substrates more robust than on low ground Normal high montane rainfall leaves paths better equipped to deal with down-pours Paths at mid levels protected by lesser use, lower gradients and lusher vegetation	Low absorption of hard rocks, thin soils and vegetation Most upland paths are built on the fall and desire lines Steep gradients leading to wash-out Historic path-work not as well specified as today Poor choice/use of materials Peaty ground More folk going out in extreme weather Insufficient maintenance of drainage features Generally poor path management practice Snow lie in path tray Walkers avoiding snow and ice on path line
Opportunity	**Threat**
Enhanced vegetation growth on path surface and adjacent damaged ground Fewer walkers and less pressure on paths x2 Need for improved path management practices Make better use of local materials Reduce gradients by re-alignment	Insufficient or no maintenance x3 Reduced funding x2 Over-constructed routes being avoided/bypassed by users Higher rainfall leading to gross wash-out Authorities losing heart/giving up after catastrophic events, eg major wash-out Competing priorities, eg between upland paths and low-ground, community networks: a political issue/choice Late summer thunder-storms leading to major wash-outs, eg of granitic surfaces Slope instability leading to path being undermined, slumped out or covered by material

How are from 'acceptable' are your paths?

Completely unacceptable — Total acceptable

			x		x x		x		

What influenced your scoring?

- That paths will at least be accessible and available into the future
- Future impacts on paths and landscape condition
- The expectations of users in the hills is less than in the lowlands
- Physical condition of paths: construction, drainage, material choice, surfacing and sub-base
- Path edge "obstruction" techniques will keep folk on the path line
- Regular maintenance, including a mechanism, eg a maintenance team
- Level of awareness and expertise/sharing best practice
- A perceived difference between paths in benign NGO ownership and private ownership, perhaps as public investment not so secure in latter? This may be historic
- Shared use of paths as threat

It should be noted that many of these criteria could have positive or negative scores but these factors influenced participants evaluations

What needs to be adapted to cope with extreme weather and climate change?

Planning	Construction	Maintenance	Management
More robust construction on the more popular paths Strategic path planning, using detailed audits and a risk assessment process Location crucial Sustainable alignments away from fall-lines x2 Look at weather history/frequency of extremes: adapt if possible for snow-fall/ rain changes Plan to replace/renew structure/surfaces more often Spread user load	Much higher standard needed More adventurous use of materials and techniques More bound surfaces? Tackle loss of fines in drought/windy conditions Increase drainage features and capacity x2 But remember Natura sensitivities and ensure balance!	Improve routine maintenance Carry out pre-emptive work Increase monitoring and recording Attempt comparative evaluation of high-build and light touch paths if practical Engage voluntary and local assistance Debate over effectiveness of maintenance in face of extreme events	Has to be committed and ongoing Long-standing problem of capital vs. revenue and poor timing ('seasonality' of budgets) Need for wide-spread awareness-raising; audiences to include funders, governance, management, as well as path managers/ practitioners Develop reserve fund for catastrophic events; how do Transport Depts manage this?

The issue of maintenance could be controversial. Extreme events can overwhelm path features, suggesting that maintenance would be of little consequence. On the other hand, perhaps more likely is a gradual increase of steady rain-fall (as opposed to snow) requiring more rigorous maintenance of drainage features...

What skills are needed to help solve the issues you have identified?

- Ability to ensure delivery of appropriate work, inc the balance between aesthetics and over-engineering: work designers and contract managers
- Develop better advice and knowledge re design adaptation to extreme events
- Accept geographic variation; skills need to be site-specific as well as generic
- Develop better knowledge of soil and slope instability
- Test suitability of materials
- Be responsive as we learn more about climate change and likely impacts
- Translate climate change knowledge to path managers (Chris, you have the job!)
- Offer a national overview but with local interpretation and advice
- Develop skills in revegetation
- Be innovative in techniques; attract new talent into the industry
- Raise awareness of potential impacts of climate change among funders and government
- Establish demonstration sites
- Share information and experience, eg via SATIN

Break-out session - ‘other paths’

On the basis of the potential changes in climate predicted and the extreme weather being experienced, how do paths that you manage ‘shape up’

Strengths	Weaknesses
Extensive low ground network – lots of investment over 15+ years Better understanding of networks Range of surfacing materials Sharing of technical knowledge Existing network in reasonable condition – new bridges, drains etc Good design & well planned paths Strong community buy-in, largely reinforced by core path planning process Relatively easy access for maintenance (often machine access)	Paths in wrong location x2 / Paths in vulnerable location – along coast / rivers / poor quality land that has no other use Lack of maintenance x2 Paths don’t join up Can’t cope well with multi-use Dealing with legal issues / timescales Vulnerable to changes in water table? More likely to be constrained by land use issues than upland paths Poorly designed infrastructure Surrounding land use can have big negative impact

Opportunities	Threats
Core paths and other high profile access news may create funding opportunities Learning from mistakes or challenges Need for soft / sustainable solutions Aim for good path management Better prioritisation for important paths Information about area flooding and risk Community growth development – new networks Core path planning [Housing] Development activity	Lack of maintenance More paths located in vulnerable areas Resources / Funding x3 Incised river valleys / landslips Difficult to justify resources for ‘1 in 50 year’ event Core path planning [Housing] Development activity

How far from ‘acceptable’ are your paths with respect to climate change

Completely unacceptable Total acceptable

		x		x		xx			

What things most influenced your ‘scoring’, and why?

There is probably a split between the ‘robustness’ of paths depending on whether they are rural / urban...

Rural – likely to be built to ‘lower’ standard / informal routes
Urban – more highly engineered, higher standards

[For more highly scored]

- Dealing with relatively new infrastructure
- Proximity to ‘vocal communities’ – tends to result in better paths, more likely to be robust

[Lower scoring]

- ISSUE – loss of use during extreme weather, particularly cold snaps – gritting of cycleways?
- Recent experience has reduced confidence in the infrastructure to cope, and the frequency of return events
- Networks have been a victim of their own success and people have increased expectations – could lead to problems if standards / availability of paths decrease

How to move towards ‘Acceptable’

- Undertake a strategic assessment of network – to work out how robust it is... Could be done with the core path plan (but hasn’t been)
- LOCATION – it is a conundrum... core path planning process has demonstrated where people WANT to go, but these are often more fragile (coast / rivers)
- Local Authorities are likely to be more responsive now than previously – they have a better awareness of Climate Change and of the importance of path networks
- Work to adjust the expectations of users (i.e. it might not be possible to maintain a coastal path to a high standard)
- Examine the ‘wider catchment’ to assess land use – look for opportunities to move paths to more sustainable places.

What needs to be adapted to help you cope with extreme weather and climate change?

Planning	Construction	Maintenance	Management
Influence development planners and SRDP (case officers and RPAC) Fit paths within an overall framework – e.g. a strategic risk assessment Investigate cost effectiveness of 'heavier engineering' Improve microscale path alignment Do better homework on 'wider area' – land use / drainage Think about making some routes 'seasonal' Think about relative impacts of 5 / 50 year events Consider SUDS Involve local people / knowledge	Ensure all paths are fit for purpose (or fit beyond present purpose!) Look at cost effectiveness and whole life costs Potentially build key links to higher spec Consider the 'edge effects' on the boundaries between hard and soft engineering Learn from experience (good and bad) Learn from other countries / conditions Consider seasonal infrastructure **Conduct trials (and share the outcomes)**	Use local knowledge and experience Develop inspection regimes Include maintenance in the whole life costs Solve the problem of accelerating drainage (i.e. it can cause problems within the path or beyond it)	Improve skills and training (e.g. inspection) **Awareness training for funding bodies** Look at the use of structural funds to cope with extreme events Highlight the issue of getting resources for repeated impacts / events

What skills are needed to help solve the issues you have identified?

Groups focussed on identifying specific differences between different path settings, rather than skills requirements...

Coastal	River	Rural	Urban
Need to understand more about the implications of storm surges	The path needs to be set in a wider corridor than the watercourse to enable adaptation	Need to understand the implications of ground saturation caused by extended wet periods Consider the implications of land use changes (e.g. agricultural patterns) and their affect (e.g. downstream drainage) What are the implications of paths being located in woodlands (both existing / mature plantations and new native schemes	Will there be a problem with melting bitmac? Take a SUDS approach to design Look at the consequences of further building developments

Issues to consider with 'hardening the resource'

It is easier to do (in terms of perceived acceptability) in the lowlands / near settlements. However careful consideration of aesthetics and maintenance are needed. There might be some conflict between allowing 'lower' standards in order to deal with climate change and the agenda of 'active travel' (people will prefer high quality surfaces!)

There is also a difficulty with standards and encouraging access – people who are not accustomed to exercising a right of access might expect higher standards (e.g. for comfort and personal security) but may not be possible if encouraging 'less formal' expectations (e.g. coastal paths).

Plenary session discussions

Guidance – how should it be developed to be of most use

Important not to repeat / duplicate existing guidance – in needs to say something new
Can signpost to existing guidance

Select examples from other environments / countries. Include BUFT 2005 Bangor Conference

Review the existing manuals and take the best bits – potentially replace pages rather than whole sections

Overview needed (of CC as well as implications) followed by greater detail.

May be useful to develop a non-technical summary of CC & paths for other audiences – to 'sell' the concept – as a promotional tool (particularly land managers and funders)

Include a checklist / flow chart for path planning: develop the concept of risk analysis / environmental assessment – how to do it.

Explore how far we need to change emphases in current practice rather than refined techniques or completely new techniques

Find case studies – are there comparable sites that are being managed differently that could highlight differences / similarities

Other guidance that needs to be included – Countryside for All / DDA compliance

Identify potential trial sites. [But not clear how to identify them and communicate the outcomes]

Which format(s) are most useful

Web based is good – easiest to keep up to date, but some people need hard copy – a PDF is helpful rather than need to print individual pages. Need to consider 'offline' access

Could include a flyer (e.g. SNH sensitive sites guidance) or produce CD version

The output should make recommendations about the scope of changes within guidance as the 'answers' are not generally accepted (i.e. too much uncertainty or no agreement on solution). It may not be possible to write the actual guidance as part of this contract.

Separate out 'promotional tool' and good practice guidance – two 'publications' with two separate audiences

RA, PJ, CY 19/10/10

Appendix 2: Upland Pathwork – Construction Standards for Scotland

Section 1 Introduction to Upland Pathwork: a very useful overview, made up of 8 sections. We would suggest adding a ninth section:

1.9 Climate Change
Upland path erosion is caused by the interaction of human pressure, vegetation and soils, and the weather. Scotland's weather, with high rainfall, variable snow cover and regular freeze/thaw cycles, is conducive to the rapid development of path erosion once protective vegetation is worn through.
Climate change is recognised to be changing weather patterns in the uplands and it is predicted that these changes, and their impacts, will become more marked in the years ahead. It seems likely that there will be:

- a continuing reduction in snow cover
- shorter periods when the ground is frozen
- potential for an increase in freeze/thaw events at higher altitude in winter
- increased precipitation in the winter months, either as rain or snow that quickly melts
- drier and warmer summers
- more frequent thunderstorms and torrential rain events

Potential impacts of this changing pattern of weather may include:

- path surfaces being less protected by snow and ice, becoming water-logged and losing coherence
- path surfaces and adjacent bare or recovering ground being exposed to more frequent freeze/thaw and breaking up as a consequence
- path surfaces being washed out by the above processes, and by increasingly heavy rain and unconsolidated snow, and rapid snow-melt
- drainage features being unable to cope with torrential downpours
- bridges and associated revetments being undermined or washed away in flood conditions
- ditches being eroded by pressure of water flow
- land slippage when ground becomes super-saturated
- fines being blown out of path surfaces during drought conditions
- revegetation works not taking during drought conditions
- revegetation rates enhanced by longer growing season
- personal safety of path workers being compromised during extreme weather conditions

Risk assessment during project development should take account of possible weather impacts. It may be useful to think of chronic and acute impacts derived from a changing climate.

Acute impacts, such as major land slippage or overwhelming of path infrastructure by water after a deluge, are unpredictable and difficult to plan and manage for. But path planning may be able to identify where such events are likely to occur and to suggest an alternative route or alignment on higher or more stable ground.

Chronic impacts, such as higher winter rainfall on path surfaces less protected by ice and consolidated snow, require more obvious management responses, for instance in terms of well-compacted path surfaces, frequent anchor bars, more frequent inspection and regular maintenance.

The addition of a stand-alone sheet with general points might obviate the need for frequent, small additions within the following technical information sheets.

If the whole document is to be revised in the future, amendments might include:

Section 2.0: Introduction to drainage techniques – this needs redesigned to match the other subject intro sheets (see 3.0 and 4.0). It could be rewritten with less emphasis on stone construction and more on wider drainage and path protection.

Section 2.1: Ditching – it has been suggested that there needs to be a new information sheet on turf-lined ditches. If this is not to be progressed, there does need to be mention of this increasing practice within 2.1, a practice developed in the Cairngorms to cope with large area of snow-melt coupled with rain, so more widely applicable to deal with climate change impacts. Such ditching will be much wider and more open in construction, reflecting that it is almost invariably carried out by machine. It reduces scour effect by providing a more robust hard-wearing surface and in part by spreading the drainage channel area. It tends also to be a less intrusive intervention within a wild land setting. It can also be used effectively some distance from the path to divert run-off away from the path locale; however, such wider scale drainage needs to be balanced against nature conservation interests and constraints.

Section 2.4 and 2.5: Stone and piped culverts – they might both benefit from a further emphasis of their proneness to blocking and inability to cope with higher water flows (in both cases it is mentioned under maintenance). They may not cope with extreme weather events as well as an open system, such as cross drains or stone fords.

Section 2.7: Stone ford – this sheet could usefully emphasise the ford’s value in critical areas subject to large fluctuations in run-off/water levels, as well as its compatibility with a range of recreational activity (on the other hand walkers may need to become more adept at burn hopping or more tolerant of wet feet).

Section 3.0: Introduction to path surfaces – this should probably be rewritten, to take account of evolving practice and the increasing effect of mild, wet winters on path surfaces. Issues that might be included are:

- finding the most sustainable route
- ensuring new path surfaces are well bound/compacted; time needs to be taken to secure, use and batter down an appropriate surface; this can work with Cairngorm granite!
- cambering the path surface to shed water laterally
- raising the path surface above the surrounding ground
- constructing sufficient anchor bars
- using machinery wherever possible
- adhering to maintenance requirements

Appendix 3: Upland Path Management

Overall this publication is much more about the processes associated with path project planning and delivery, rather than the technical issues surrounding path management in a changing climate. As a consequence there are few places where amendments would fit, and in general terms they may not be required in a document such as this.

It would, however, be worth considering an amendment to page 18: “developing a path management plan/risk management/how sensitive is your project to variables across a range of factors?” Within this box an extra bullet point could be:

> Climate change: changing weather patterns associated with climate change introduce a degree of uncertainty into project specification. Paths may have to cope with more intense rain events and more frequent freeze/thaw cycles; drainage features may have to be more robust in construction, and more extensive in location, whilst path surfaces may need to be hardened and better able to shed water.

Other sections of the guidance where the climate change message could be strengthened include:

Page 3: Sensitivity to erosion – a bullet point could be added:

> The effects of climate change on Scotland’s weather patterns are now recognised. There is less snow cover on the hills and more freeze/thaw events each winter. Rainfall is increasing in the winter months and torrential rain is becoming more frequent at any time of the year. These factors exacerbate the impacts outlined above

Page 77: Risk assessment – whilst lone working, remoteness and weather are all listed in a list of tasks and hazards, it might be as well to spell out more detail as a prompt to managers, e.g. burn crossings, extreme weather events, sun-stroke

Page 115: dealing with variations – after the sentence “During the construction it is inevitable that some changes will need to be made to the specification” the following text could be added:

> Sudden weather events may intervene: rapid burn rise and flash flooding after a summer thunderstorm may reveal weaknesses in the original specification. Such extremes of weather are now becoming more common under the influence of climate change

Appendix 4: Lowland Path Construction Guide

The guide was rewritten by Walking-the-Talk at the same time as this research was undertaken. Therefore the issues highlighted were incorporated into the new document, particularly in terms of risk assessment and network planning. A new section relating to climate change was added as part of the introduction to path management, meaning that this information is integrated with new guidance, rather than 'bolted-on'.

The following text was drafted for incorporation:

Planning for climate change
Scottish Natural Heritage commissioned a report in 2010 about how path management is likely to be affected by climate change. The overall message was the need for careful long term planning by assessing and controlling the risks associated with predicted warmer wetter winters and drier summers. Climate change models also predict that extreme weather events (storms with high intensity rainfall) will become more frequent and that there will be increased risk of damage around coastal areas as a result of sea level rise.

There are two aspects to the predicted impacts of climate change:
Chronic impacts – slow continuous deterioration caused by the gradual change in weather patterns over an extended period of time
Acute impacts – rapid deterioration caused by severe weather associated with a changing climate.

It may not be possible to eliminate the risk posed by acute impacts and it is almost impossible to predict the probability of extreme weather occurring at a defined location, but this should not be used as an excuse to avoid forward planning. Approaching lowland path management in terms of creating and managing path networks provides a useful perspective for dealing with the challenge of climate change. Looking at a network as a whole gives you an opportunity to identify 'weak links', or critical points where action would be required in the event of acute impacts occurring and to look for alternative options to keep a network 'functional'.

There is very limited 'generic advice' that will be useful, because of the enormous variation in paths across Scotland. Therefore a standard risk assessment process can be used to identify the climate change hazards for your network, their probability of occurring and the scale of impact. This produces a risk score (Risk = probability x scale) which can be used to identify high, medium and low risks. These should be sub-divided into risks associated with Chronic and Acute impacts as they may require different adaptation approaches.

For each high risk impact a 'control' or adaptation needs to be devised, which will provide a practical response to predicted climate change for the path network. This could include actions that can be taken in advance, such as changing the specification of drainage features to cope with increased surface water, or to identify (and hold) contingency funding to deal with very low probability but catastrophic events.

Some of the climate change hazards will be specific to the location of your paths – for example riverside paths may become more liable to flooding in wetter winters (Chronic impacts) and bridges could be at greater risk of damage from extreme flood events (Acute impacts). It is therefore important to use local knowledge of the landscape to plan your network to avoid unnecessary risks (e.g. multiple bridge crossings) or to look for adaptations to existing infrastructure to cope with predicted changes (e.g. upgrade surfacing to semi-bound or sealed-surface). Planning ahead can allow you to prioritise tasks so that you can make adaptations of a number of years, rather than needing to use emergency funds when something catastrophic occurs that could have been prevented.

Coastal paths are an extremely popular concept and have been built to varying standards across Scotland. They are, in many cases, susceptible to damage during extreme weather events and there may be limited options for providing alternative routes where damage does occur, e.g. following storms. Careful consideration about the long term planning and management of coastal paths is therefore of high importance to ensure that existing investments are adequately protected and unsustainable schemes should be avoided, even where there is demonstrable demand.

Climate change may also bring opportunities in Scotland, particularly if summers do turn out to be warmer and drier as predicted. More people may be inclined to use paths and increased demand could be beneficial to securing resources for more and better paths. Providing opportunities for ‘active travel’ could also help to encourage more people to switch away from using motorised transport and thereby reduce society’s impact on the environment.

Appendix 5: Path Bridges Guidance

This is a relatively new publication (2006) and mentions climate change as a passing reference. However it would benefit from a few additions and alterations...

1.5 Climate change (new section) – this needs to cover the likely effects of Climate Change with particular reference to intense rainfall events and flooding potential:

> **Climate change** is recognised to be changing weather patterns in the Scotland and it is predicted that these changes, and their impacts, will become more marked in the years ahead. It seems likely that there will be:
>
> - a continuing reduction in snow cover
> - shorter periods when the ground is frozen
> - an increase in freeze/thaw events each winter
> - increased precipitation in the winter months, either as rain or snow that quickly melts
> - drier and warmer summers
> - more frequent thunderstorms and torrential rain events
>
> **Potential impacts** of this changing pattern of weather may include:
>
> - bridges and associated revetments being undermined or washed away in flood conditions
> - land slippage when ground becomes super-saturated
> - personal safety of path workers being compromised during extreme weather conditions
>
> **Risk assessment** during project development should take account of possible weather impacts. It may be useful to think of chronic and acute impacts derived from a changing climate.
>
> **Acute impacts**, such as major land slippage or overwhelming of bridge infrastructure by water after a deluge, are unpredictable and difficult to plan and manage for. However the planning process may be able to identify where such events are likely to occur and to suggest an alternative location or route to avoid the need to build a bridge.
>
> **Chronic impacts**, such as higher winter rainfall require more obvious management responses, for instance in terms of more frequent inspection and regular maintenance.

5.6 Maintenance: The guidance does not suggest recording height of recent floods – it would be useful record this information as a matter of course to help build up a picture for future managers and other sites.

5.7 – Upgrading existing structures: Add a short section to determine if the existing design / site sufficient for predicted climate change (particularly if it is old infrastructure)

Technical Sheets
6.2 – Flood Level Estimation. Needs to consider predicted climate change where flood data is not available – the guidance suggests using local knowledge, but does not include using predicted increases in rainfall when calculating future requirements.

Appendix 6: Non-technical summary

Scottish Natural Heritage
All of nature for all of Scotland

Climate change and paths
a briefing note

In a world where the news headlines report extreme floods, widespread forest fires caused by droughts or communities at risk from sea level rise, it may not be too difficult to make a connection that such events might occur in Scotland. These events may all be symptoms of more general climate change, and this could have adverse consequences to Scotland's environment, society and economy. We will need to be prepared to adapt to such changes.

The following account of potential impacts of climate change on paths is aimed *primarily* at those who have responsibility for developing or influencing policies and allocating resources for outdoor recreation in Scotland. It may also provide a useful overview of climate change issues for those currently involved with the development and management of paths.

The key issues are:

- Dealing with impacts of progressive change to the climate and responding to extreme weather events
- Managing risks to paths and path networks through effective planning and resource management
- Sharing knowledge and understanding of best practices

The nature of climate change in Scotland

Research undertaken by Walking-the-Talk for Scottish Natural Heritage has looked at the potential influence of climate change on the design, construction and management of paths and path networks across Scotland. The objectives of the study were to understand the potential impacts of climate change and identify potential adaptation strategies to protect the significant investment that has been made in paths, and in encouraging healthy, and more sustainable lifestyles.

Predictions of climate change used in the research were taken from a range of models, of which the UK Climate Programme (UKCP09) is regarded as the standard for the UK. The generally accepted range of predictions from these models presents challenges and opportunities for management of paths in Scotland. The overall climate picture is one of milder, wetter winters and warmer drier summers in the decades to come. We are likely to see wider fluctuations in weather conditions around the climatic average, with predictions of the wettest day in winter, for example, having up to 30% more rainfall by the 2050s. Extreme weather events, such as intense rainfall, are also predicted to become more common in this time frame. Recently published climate research suggests that Scotland's 'insurance policy' against sea level rise, the continuing uplift of the land since the last ice-age, will not be able to keep pace with predicted rises in global sea level during the coming decades.

Potential impacts of climate change on paths

There is a degree of uncertainty within the climate predictions, which makes it difficult to translate these into quantifiable changes to path condition as a result of climate change. However, there are two main types of impact that are likely to result from climate change. The general trend of climate conditions towards warmer, wetter conditions will present cumulative, ongoing pressure on paths, which can be regarded as causing **chronic pressure**. However, the more extreme weather events that are predicted to occur will give rise to **acute pressures**.

Impacts arising from chronic pressures

Wetter winters will increase the erosive force of water on drainage ditches and path surfaces. Whilst this increase may be most marked in the north-west, existing routes and path surfaces in this area may already be designed to cope with current high rainfall.

Warmer winters will lead to less snow cover and extend the growing season and raise the altitudinal growth range for plant species. In the uplands this will enhance re-vegetation, which in turn protects path edges.

Decreased snow and ice cover in the uplands will reduce the protective insulation that binds the soil and vegetation during the winter months, exposing them to trampling and scouring by water. This chronic effect will have significant consequences for path condition and management. Although in winter off-path damage is reduced or prevented by snow cover, predicted decreases in snow cover potentially allows more widespread damage to habitats where people stray from defined path lines. Reduced snow cover may also encourage more people to take to the hills who might otherwise be put off by their lack of the specialist skills and equipment required in winter conditions.

Longer growing seasons may result in the need for more vegetation management, particularly on lowland paths.

Drier and warmer summers may have a positive impact on demand for recreation and may change the patterns of use, potentially increasing pressure on paths.

Impacts arising from acute pressures

Intense rainfall has the potential to cause acute impacts in all path settings. It will increase the scour on path surfaces and can lead to large-scale wash-out. It also increases the demands and pressure on drainage features - ditches can be eroded by the sheer force of water and drains may not have sufficient capacity to cope. Revetments may be undermined and collapse, and bridges will be washed over and may even be washed away. Such events also have the potential to be a danger to both recreationists and path workers who may have return routes suddenly swamped and unsafe for passage.

Saturated soils will result in water-logging of some path surfaces and consequent trampling damage. The most severe and acute damage is likely to occur from adjacent ground slumping onto a path or taking the path with it - recent evidence suggests that this is a localised problem within the southern/central Highlands.

Storm force winds associated with extreme weather events may cause acute damage to woodlands which could result in direct or consequential impacts on paths.

Understanding the implications for paths and outdoor recreation

The headline-grabbing **acute impacts** caused by distinct, extreme weather events may be highly localised and almost impossible to predict with any certainty, but are likely to cause major damage to path infrastructure. There is, however, some limited scope to adapt or avoid acute impacts. Depending on the scale of the event, paths that are in poor condition are less likely to be able to absorb the impact of extreme weather, potentially resulting in greater damage than adequately constructed and maintained paths. Contingency funds will be required to respond to these one-off impacts, although paths may not be considered a high priority for government or the public compared with other parts of the transport network or utility infrastructure. Funders may have to accept that path managers will need additional resources to repair key routes damaged by acute events, including previously funded paths where gross and unexpected damage has occurred.

More insidious are the **chronic impacts** caused by ongoing changes to the climate, such as the wetter conditions in winter, potentially resulting in gradual deterioration in path condition. It may be difficult to attribute these impacts directly to climate change. Chronic impacts have the potential to affect all paths in Scotland and the effects will be seen over periods of years, and possibly decades. Some of the impacts may result from the climate itself, whereas others may be secondary impacts, such as increased path use, brought about by improved summer weather, leading to more pressure on paths.

Detecting and responding to chronic impacts is reliant on continuous vigilance through regular inspection and ongoing care of paths. Paths that are properly constructed and managed to existing standards are likely to be able to withstand the chronic impacts of climate change. Therefore adequate resources need to be available for all aspects of path management to safeguard the investment made to date and to prevent unnecessary deterioration of paths caused by incremental changes in climate.

Responding to the challenge of climate change

There are challenges that need to be addressed to assist with adaptation to climate change, some of which inevitably revolve around the allocation of resources for ongoing management.

Managing risk

In order to better understand the nature and scale of the implications for paths, a risk management approach is recommended – a formalised process of identifying hazards from climate change and ‘quantifying’ the risk in terms of potential severity and probability of these hazards occurring.

A risk management process will help to pinpoint weaknesses in design or management of path infrastructure and provides a mechanism for developing adaptation strategies for each path or path network. For example, a path network that has multiple river crossings could be heavily impacted by extreme flood events, so identifying alternative links that do not require crossing the river could help to make the network more resilient to this acute impact if it were to occur.

This approach provides a framework for proactive management of paths and path networks, helping to allocate resources more strategically in the development and maintenance of paths, as well as providing potential options and guiding actions in the event of the more extreme predictions becoming realised.

Learning and sharing knowledge

Improving the sharing of experience and knowledge about managing paths in harsh conditions and responding to the acute impacts of weather is likely to have a positive impact on path management in Scotland. For example, some of the variations currently used for upland paths in areas of high rainfall (e.g. on the west coast), such as the sizing of drainage features, may become increasingly relevant to other parts of the country, including lowland paths. There is also scope to investigate ways of improving specific construction techniques such as revegetation and retaining unbound surfacing, as well as improving maintenance techniques and options for delivering maintenance.

These activities may involve an injection of investment in the short term, but would lead to long term efficiencies and improvements in standards.

Counting the cost of climate change

With the degree of uncertainty that is associated with climate change models it is difficult to quantify the overall cost of climate change for path design and management in Scotland, particularly from acute impacts. However, this should not obscure the main implication regarding the cost of ongoing care of paths: chronic impacts of climate change mean that poorly maintained infrastructure will not be resilient; inadequate maintenance may exacerbate acute impacts and is likely to incur greater capital costs to remediate. Some examples of likely costs have been put together as a first attempt, but these will need to be revised as further information becomes available:

- An additional 10% maintenance costs has been estimated for upland paths that have a costed maintenance plan. For example, Cairngorms Outdoor Access Trust had a 2010 budget of £30,000 per annum to manage 93km of upland paths, meaning that an extra £3,000 per annum would be needed. This 93km represents a small fraction of the total length of upland paths in Scotland, many of which do not currently have costed maintenance plans.

- If future climate conditions result in more vigorous plant growth or longer growing seasons this could have a cost implication for vegetation management on lowland paths. It is likely that these costs could rise by approximately 13-20% per annum.

Path managers may see benefits to upgrading the specification of some lowland paths to, for example, sealed surfaces such as tarmac, in order to produce a more robust path with reduced ongoing maintenance. This would provide a high quality resource, potentially suited to a range of users, although it could result in a much reduced total length of path constructed owing to the significantly higher capital cost of development. Other, more minor, adaptations could be made to specifications, mainly related to improving the drainage capacity, and these would have a measureable increase in cost compared with current specifications.

Recommended actions to prepare for climate change

The main recommendations from the research are:

- **Implement a risk management approach** to paths and assess the climate related risks for each path or path network in Scotland.
- **Secure resources to design and construct all paths to minimum standard** as specified in Upland Paths Manual and Lowland Path Construction Manual.
- **Provide an appropriate level of ongoing inspection and maintenance** for each path adequate to prevent it from deteriorating from chronic impacts of climate change.
- **Investigate techniques and materials that will provide robust paths** whilst minimising the environmental impact of path construction and management.
- **Share existing good practice in long term path management** and promote a range of options to control the risks associated with potential climate change.

For the full report please visit the website of Scottish Natural Heritage [link to publications]

Appendix 7

Assessing the risks that may result from climate change

Stage 1
This information should already be available for managed paths. Describe the key features of the path – summarise the type of construction, how they are managed (e.g. annual inspection, ad hoc repair etc.), and the costs associated with management (5-year total).

Stage 2
Consider each group of pressures / potential impacts independently – i.e. chronic and acute. Consider the likely hazards for each path feature that will result from the changed conditions.

- For each hazard consider the magnitude of potential impact from 1 (localised / very minor) to 5 (extensive / major) on each path feature.
- Then consider the probability of those hazards affecting the path features 1(highly unlikely) to 5 (very likely) – this is an assessment of how susceptible the path is to the hazard rather than the probability of climate change happening.
- Multiply the magnitude by the probability to produce a risk score for each path feature.

Risk scores

Hazard		Magnitude of impact should it occur				
		1	2	3	4	5
Probability	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

High risk	Higher priority for action
Medium risk	
Low risk	
Negligible risk	Lower priority for action

Stage 3
For the high scores, there is a greater need to identify ways of controlling or adapting to the risk. This should include identifying potential costs (or labour / plant requirements) and delivery options. A monitoring scheme should be put in place to give early warning of impacts. In some circumstances there may not be a way of controlling the risk and an 'exit strategy' or contingency plan will be required – this may be the abandonment of the route (rather than repair) or investigation of alternative construction method / routing.

For medium scores a less detailed appraisal of options is recommended to provide controls or adaptations and a monitoring scheme put in place.

For low scores the risks should be monitored to ensure that there are no changes to the risk factors and any opportunities that arise to increase resilience should be investigated.

Climate hazards and potential impacts on Lowland Paths

		Drainage	Surfaces: Natural	Surfaces: Unbound	Surfaces: Sealed	Engineering features	Bridges	Vegetation management	Adjacent Ground	Path management Staff	Recreational Users	Access-ibility
Chronic Impacts	Wetter winters	X	XX	X	~	X	X	X [1]	X	X	X	*X*
	Warmer winters	~	~	~	~	~	~	X [1]	~	+	+	~
	Saturated Soils	X	XX	X	~	XX	~	XX [1]	XXX [2]	X	~	*XX*
	Longer growing season	X	~	~	~	~	~	[1]	~			
	Warm, drier summers	~	~	X [3]	X [4]	~	~	~	~	?	+	+
Acute Impacts	Intense rainfall	XX [6]	XXX	XX (X) [5]	X (XX) [5]	XX	XXX	X	XX [6]	X	X	*XXX*
	More high winds	~	~	X [3]		?	~	~	XXX [7]	X	X	*X*
	Storm surges [8]	XXX	XXX	XXX	XXX	XXX	XXX	?	XXX	XX	XX	*XXX*

Notes: X has a negative impact (degree of negativity is implied by the number of Xs), + has a positive impact and ~ is neutral; ? is uncertain due to variability in features / path settings

[1] Warmer and damper conditions extend the growing season and encourage more growth but saturated soils make it difficult to gain access with machines for cutting

[2] Saturated soils, caused by a combination of warmer winters and increased rainfall, can cause major land slippage

[3] Long dry spells can lead to the break-up of unbound path surfaces, with high winds subsequently blowing out the fines

[4] High temperatures lead to premature ageing of bituminous surfaces (e.g. cracking), and can cause softening (>45°C surface temperature)

[5] Dependent on location (riverside paths are likely to suffer from the effects of flash flooding) sealed surfaces appear to fare better

[6] Paths with adjacent land use that is not 'sympathetic' to path management (e.g. surface water from roads, or land drainage for agriculture) are likely to be impacted more severely than where paths are 'integrated' into the land management regime.

[7] Woodland storm damage

[8] Storm surges have the potential to have wide ranging and catastrophic impacts on coastal paths and associated infrastructure

Climate hazards and potential impacts on Upland Paths

		Drainage	Surfaces: Natural	Surfaces: Unbound	Stonework	Bridges	Revegetation [1]	Adjacent Ground	Path Management Staff	Recreational Users	Accessibility
Chronic Impacts	Wetter winters	X	XX	X	X	X	+	~	X	~	X
	Saturated Soils	X	XX	X	~	~	~	XXX [2]	X	~	X
	Warmer winters	~	~	~	~	~	+	~	+	+	+
	Decreased snow/frozen ground	-	XX	XX	-	-	+	X	+	++	-
	More freeze/thaw	XX [3]	XX	X	X	~	X	X [3]	~	~	-
	Warm, drier summers	~	~	X [4]	~	~	XX	~	?	+	+
Acute	Intense rainfall	XX	XXX	XX	XX	XXX	X	X	X	X	-
	More high winds	~	~	X [4]	~	~	~	~	X	X	X

Notes: X has a negative impact, + has a positive impact and ~ is neutral; degree of negativity is implied by the number of Xs

[1] Warmer and damper conditions encourage the growth of transplanted turf and seedlings and extend the growing season but drought has a contrary effect and freeze/thaw can lift vegetation and intense rain may wash it out
[2] Saturated soils, caused by a combination of warmer winters and increased rain fall, can cause major land slippage
[3] Freeze/thaw lifts bare soil, a particular issue on exposed ditch sides or other bare ground
[4] Long dry spells can lead to the break-up of path surfaces, with high winds subsequently blowing out the fines

Management of climate change risks (summary description & current management regime)

Path name:

Route description:

	Drainage	Surface	Engineering features	Bridges	Vegetation management	Adjacent Ground	Recreational Users	Accessibility
Description								
Maintenance tasks								
Maintenance frequency								
Maintenance costs (5-year total)								

Management of climate change risks (assessment of hazards)

Path name:

		Drainage	Surface	Engineering features	Bridges	Vegetation management	Adjacent Ground	Path management Staff	Recreational Users	Accessibility
Chronic pressures	Hazard(s)									
	Scale of damage (1 to 5)									
	Probability (1 to 5)									
	Risk Score									
Acute pressures	Hazard(s)									
	Scale of damage (1 to 5)									
	Probability (1 to 5)									
	Risk Score									

Management of climate change risks (controls and adaptations)

Path name:

		Drainage	Surface	Engineering features	Bridges	Vegetation management	Adjacent Ground	Path management Staff	Recreational Users	Accessibility
Chronic pressures	Controls									
	Adaptations									
Acute pressures	Controls									
	Adaptations									

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